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A SERIES OF TEXTBOOKS FOR PERSONS ENGAGED IN THE ENGINEERING PROFESSIONS AND TRADES OR FOR THOSE WHO DESIRE INFORMATION CONCERNING THEM. FULLY ILLUSTRATED AND CONTAINING NUMEROUS PRACTICAL EXAMPLES AND THEIR SOLUTIONS

GASOLINE AUTOMOBILES
GASOLINE AUTOMOBILE ENGINES
AUTOMOBILE OPERATION
TROUBLES AND REMEDIES
OVERHAULING AND REPAIRS

(VOL. II)

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CONTENTS

GASOLINE AUTOMOBILES

GENERAL CHARACTERISTICS

CLASSIFICATION OF MOTOR VEHICLES

1. Generally speaking, the term *automobile* is applied only to self-propelled vehicles designed for the transportation of passengers for pleasure or social purposes. Self-propelled vehicles designed for commercial uses are commonly designated as *motor cars*, *motor vehicles*, *motor trucks*, *power wagons*, and *commercial vehicles*, the latter term being sufficiently broad to embrace them all as a class distinct from pleasure vehicles. Although automobiles are commonly hired for touring purposes, motor vehicles for the transportation of passengers for hire in cities are of two general classes, namely, *motor busses* and *taxicabs*. The latter are usually designed for carrying four passengers and considerable baggage as well. They are used extensively in large cities, where they have become very popular for making short business and pleasure trips. Motor busses are usually operated on certain main thoroughfares where there are no street-car lines. They carry a large number of passengers, some inside and some on top of the vehicle, and make regular trips at stated intervals between specified points, stopping to take on or let off passengers at street crossings whenever signaled to do so. What are known as "sight-seeing" motor vehicles are automobiles especially designed for the transportation of a large number of passengers on sight-seeing trips, the places of interest along

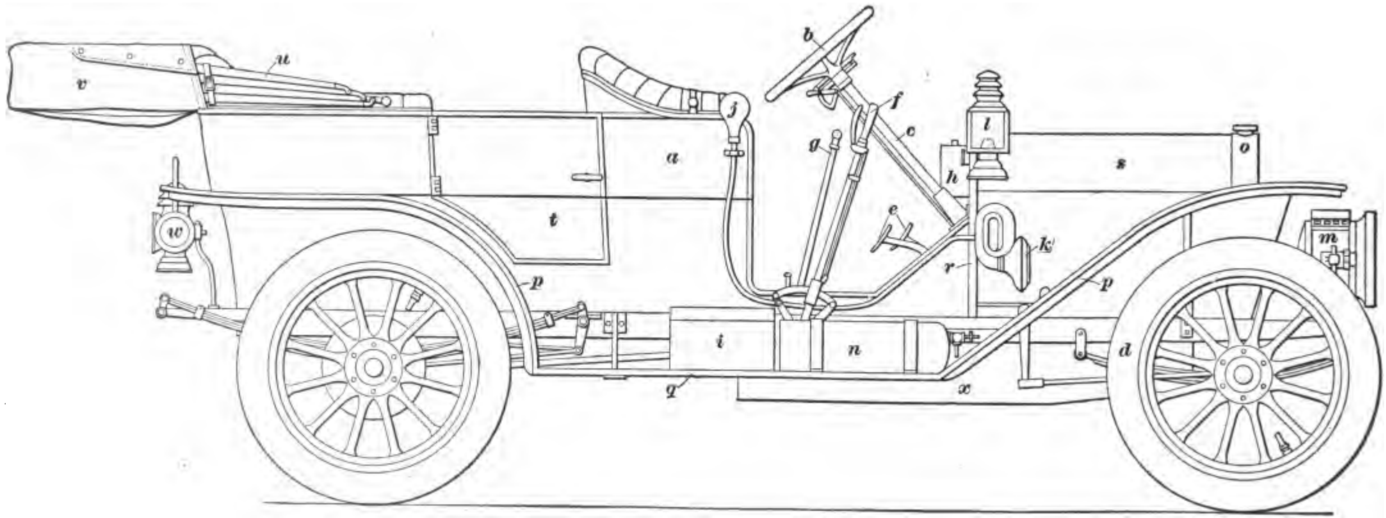


Fig. 1

the selected routes being pointed out and described by the man in charge of the vehicle.

At present, most self-propelled vehicles are driven by internal-combustion engines using gasoline as fuel, the power developed by the engine being applied to the driving road wheels by means of suitably arranged power-transmitting mechanism.

MOTOR-VEHICLE ELEMENTS

2. There are two principal parts to an automobile, namely, the *chassis* (pronounced *shah-see*) and the *body*. As originally employed by the French, from whom it has been borrowed, the term chassis was used to designate only the frame of the automobile, but as now used it applies to the assembly of the running gear, consisting of wheels, axles, springs, and frame, and the power plant, which includes the engine and transmission. In other words, the chassis includes everything but the body and its accessories. Before considering in detail the constructional features of the various elements of the chassis, attention will be given to the assembled parts of the automobile as a whole, the names, location, arrangement, purpose, and interdependent relations of the principal parts being noted.

3. A typical form of medium-sized gasoline automobile of the touring-car class is shown in Fig. 1. Just in front of the driver's seat *a* is a steering wheel *b* at the top of the inclined steering column *c*. The guiding of the car is accomplished by rotating this wheel through a portion of a revolution by hand. This rotation transmits motion to the front road wheels *d*, so as to turn them sidewise and change the direction of travel of the car.

Pedals *e* project upwards through the floor of the car, as shown, just back of the steering column. One of these pedals is for disengaging the engine from the driving mechanism; the other pedal is for applying brakes to stop the travel of the car. Each pedal is operated by pressure of the driver's foot.

At the right-hand side of the car and just forward of the driver's seat are two control levers *f* and *g*. One of these levers *f* is for throwing the engine out of connection with the mechanism that drives the car and also for applying brakes to stop the car. The other lever *g* is for adjusting the power-transmitting mechanism, so that the speed of travel of the car can be varied through a greater range than that obtainable in the engine and also for giving the car backward travel. This arrangement is useful and generally necessary in order to obtain both high and low speeds of travel, and also in order to be able to climb steep hills. A gasoline engine such as is used on automobiles rotates in only one direction and cannot be run at speeds as slow as a few revolutions per minute. The minimum speed of rotation of automobile engines is probably never as low as 100 revolutions per minute and generally not lower than 200, 300, or even more, according to the size and form of the engine. One of the side levers is called the *change-speed lever*, or *speed-control lever*. The other is the *brake lever*.

4. Just under the steering wheel are shown small levers for controlling the power and speed of the engine. Each of these levers is attached to a shaft, or tube, that extends down alongside the steering column that supports the steering wheel. One of the levers is for regulating the amount of fuel delivered to the engine and the other is for regulating the instant at which the fuel is ignited.

The lever for regulating the supply of fuel is called the *throttle lever;* the one for regulating, or varying, the time of ignition is called the *spark lever*, or *spark control*.

A spark coil *h* is shown just above the foot of the steering column. The spark coil is part of the system for igniting the fuel in the engine. Another part of this ignition system, the electric battery, is contained in the box *i* on the running board, just back of the lower ends of the control levers *f* and *g*. The battery is for supplying electric current to the ignition system. This box is sometimes used for tools instead of for a battery.

At the right-hand side of the driver's seat is a pear-shaped rubber bulb *j* connected by a flexible tube to a signal horn *k* located farther forwards at about the same level as the floor of the car. The horn is blown by pressing the bulb by hand.

5. Oil lamps *l*, generally called *side lamps*, are placed at about the same level as the seats and just in front of the steering column. Gas lamps *m* are placed at the extreme front of the car, at about the level of the tops of the road wheels. The oil lamps generally burn ordinary kerosene oil; the gas lamps burn acetylene gas, which is supplied to them either from a tank *n*, which contains the gas under compression, or from a gas generator in which water is allowed to drip on lumps of calcium carbide. The latter is a gray, or gray-black substance, generally used in lumps half an inch or smaller in size, or in compressed cylindrical form as well as in other shapes.

The top of a *radiator o* is shown at the upper part of the extreme front of the car. This radiator is for the purpose of cooling the water used for keeping the engine from becoming too hot.

6. The seats, floor, and attached parts form the *body* of the car. *Mud-guards* or *fenders p* are placed over the wheels and connected together on each side of the car by a foot-board or *running board q*.

The vertical, or nearly vertical, cross-piece *r* in front of the steering column and pedals is the *dash*. In front of the dash is a metal *hood s* that usually covers the engine. In some cars the engine is located under the body of the car, and the gasoline tank or electric battery is placed under the hood. A water tank is also often placed under the hood.

Side-entrance doors *t* give access to the rear seat in what is called the *tonneau*, and a cape top, of which the bows *u* and top cover *v* are shown, the top being folded up, is usually provided for protection against sun and rain. At the extreme rear is a *tail-lamp w*, and beneath the engine under the hood is a *mud*, or *sod pan*, *x* that protects the engine from mud and dust.

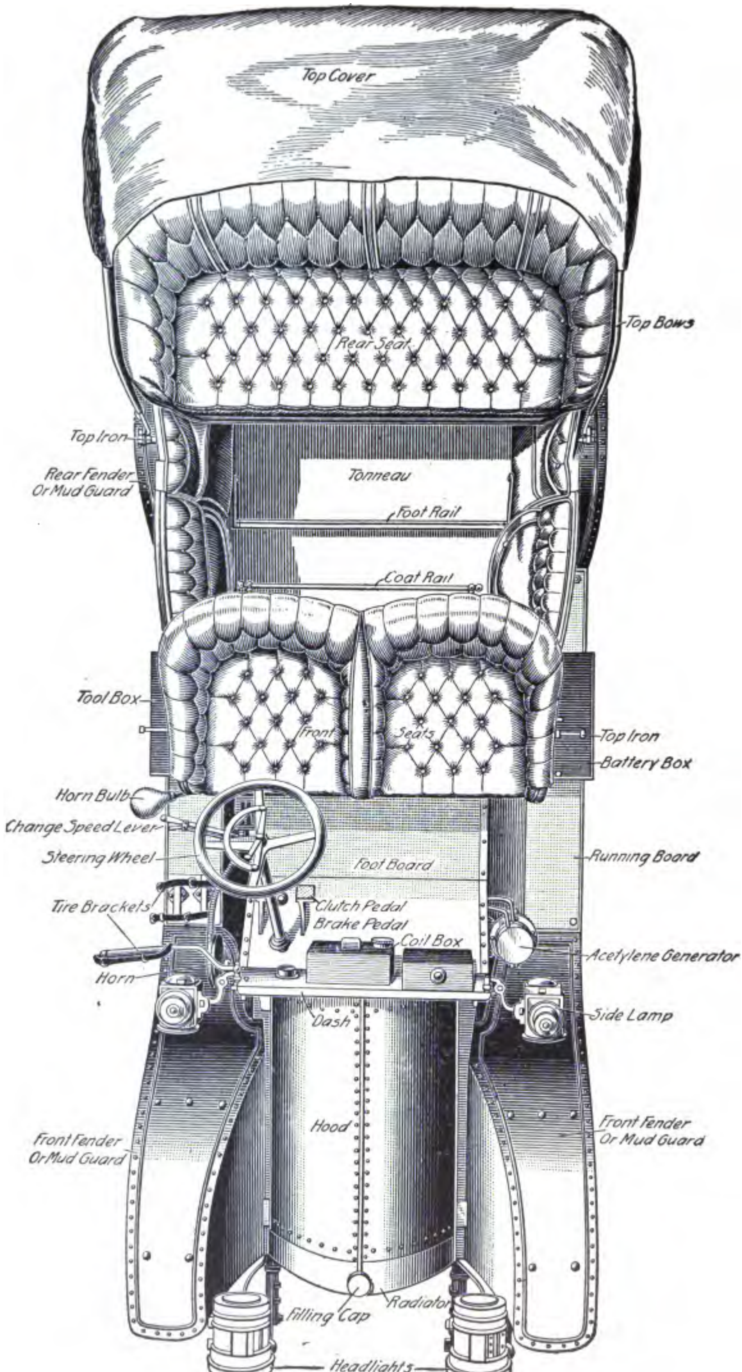

Top Cover
Top Bows
Rear Seat
Top Iron
Rear Fender
Or Mud Guard
Tonneau
Foot Rail
Coat Rail
Tool Box
Front
Seats
Top Iron
Battery Box
Horn Bulb
Change Speed Lever
Steering Wheel
Running Board
Foot Board
Tire Brackets
Clutch Pedal
Brake Pedal
Coil Box
Acetylene Generator
Horn
Side Lamp
Dash
Hood
Front Fender
Or Mud Guard
Front Fender
Or Mud Guard
Radiator
Filling Cap
Headlights

FIG. 2

7. Looking down from an elevation above an automobile similar to that shown in Fig. 1, but made by another manufacturer, the various parts appear as shown in Fig. 2, which gives a clearer idea of the shape of such a vehicle, illustrating some features that are not brought out by Fig. 1.

TYPICAL AUTOMOBILE CHASSIS

ASSEMBLY OF PARTS

8. Two views of a typical chassis of a 40-horsepower automobile are shown in Figs. 3 and 4, on which similar parts have the same reference figures. Fig. 3 is a plan view, the steering column being broken off so that the steering wheel and throttle and spark levers thereon will not hide the foot-levers, and Fig. 4 is a side elevation partly in section. Beginning at the front end of the chassis the various parts are numbered as follows:

1, Front road wheels
2, Front axle
3, Front springs
4, Front end of frame, forming hanger for front spring
5, Side members of frame
6, Headlight lamp brackets
7, Starting crank for starting engine
8, Tie-rod, distance rod or cross-connecting rod with adjustable end joining arms of steering knuckles or pivots
9, Arms of steering knuckles
10, Lever arm of right-hand steering knuckle to which one end of steering rod, sometimes called the back or rearward steering link, is attached, the other end of the steering rod being connected to the actuating lever arm of the steering gear
11, Steering rod, sometimes called the ball rod, because of its having ball joints at each end
12, Radiator in which the water for circulation in the engine water-jackets is cooled
13, Fan to create circulation of air through radiator, thus cooling water therein when car is standing still while engine is in operation
14, Cross-member of frame
15, Longitudinal members of subframe on which the engine and transmission are mounted
16, Gear-driven pump for circulating the cooling water

17, Water-delivery pipe from pump to cylinder water-jackets; also called water-inlet pipe and pump-outlet pipe
18, Water-outlet pipe conveying water from cylinder water-jackets to radiator
19, Hose connection from radiator outlet to suction connection for pump
20, Large flanged fan-belt pulley on end of engine crank-shaft
21, Small flanged fan-belt pulley
22, Standard for supporting spindle on which small fan-belt pulley and fan rotate.
23, *24*, Worm-gears for driving water pump
25, Engine water-jacket
26, Engine cylinder, shown in section to reveal piston
27, Engine piston, shown in section
28, Wristpin on which bearing in upper end of connecting-rod turns
29, Connecting-rod of **H** section
30, Crank-pin bearing of connecting-rod
31, Ball bearings of annular type on crank-shaft
32, Engine crank-shaft
33, Inlet valve controlling inflow of combustible mixture from manifold to which the carbureter is attached
34, Plugs closing openings above inlet valves, and through which latter may be removed
35, Spark plugs
36, Combined priming and compression relief cocks
37, Distributor
38, Exhaust pipe
39, Inlet or admission pipe
40, Hood
41, Radiator supporting rod
42, Crank-case breather, or relief pipe
43, Oil-filling pipe for crank-case
44, Oil supply pan in crank-case
45, Compartment containing the oil in actual use for splash lubrication, the crank-case being divided into two compartments, from the lower one of which the oil is pumped into the upper one and maintained at a constant level by stand-pipes that serve to connect the upper and lower compartments
46, Exhaust pressure regulator for regulating pressure on gasoline supply system to carbureter
47, Auxiliary hand-operated air pump mounted on dash for purpose of creating pressure on gasoline supply system
48, Gauge mounted on dash to show pressure on gasoline supply system
49, Sight-feed oiler mounted on dash
50, Dash
51, Side-lamp brackets
52, Steering column
53, Support for steering column
54, Steering chuck at lower end of steering column
55, Levers at lower end of spark and throttle control rods passing through steering column

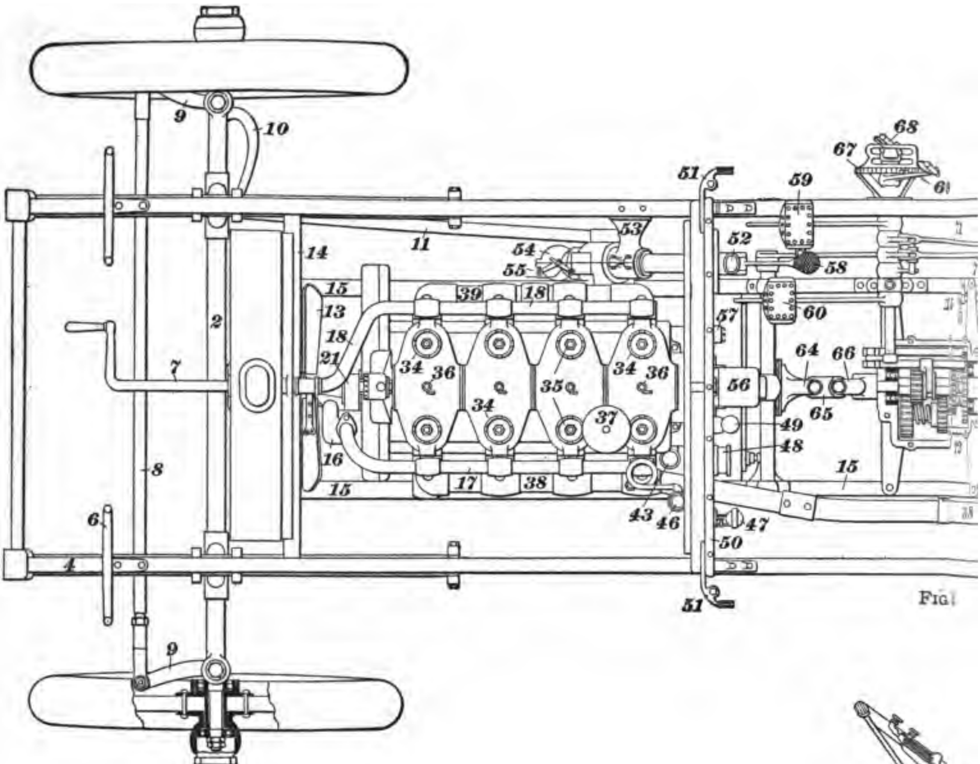


Fig. 1

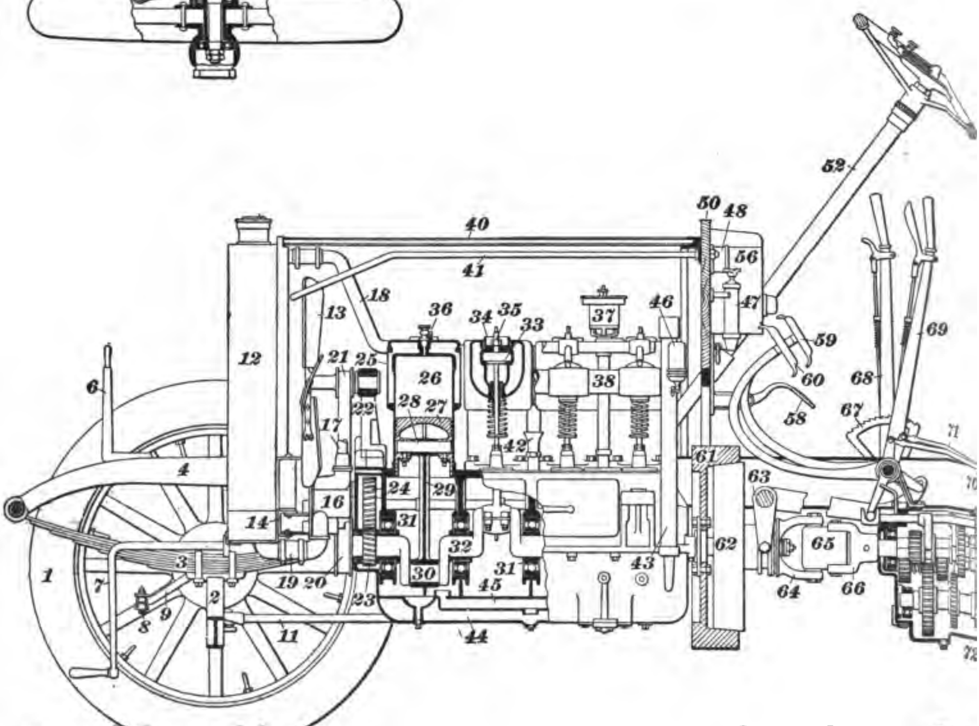
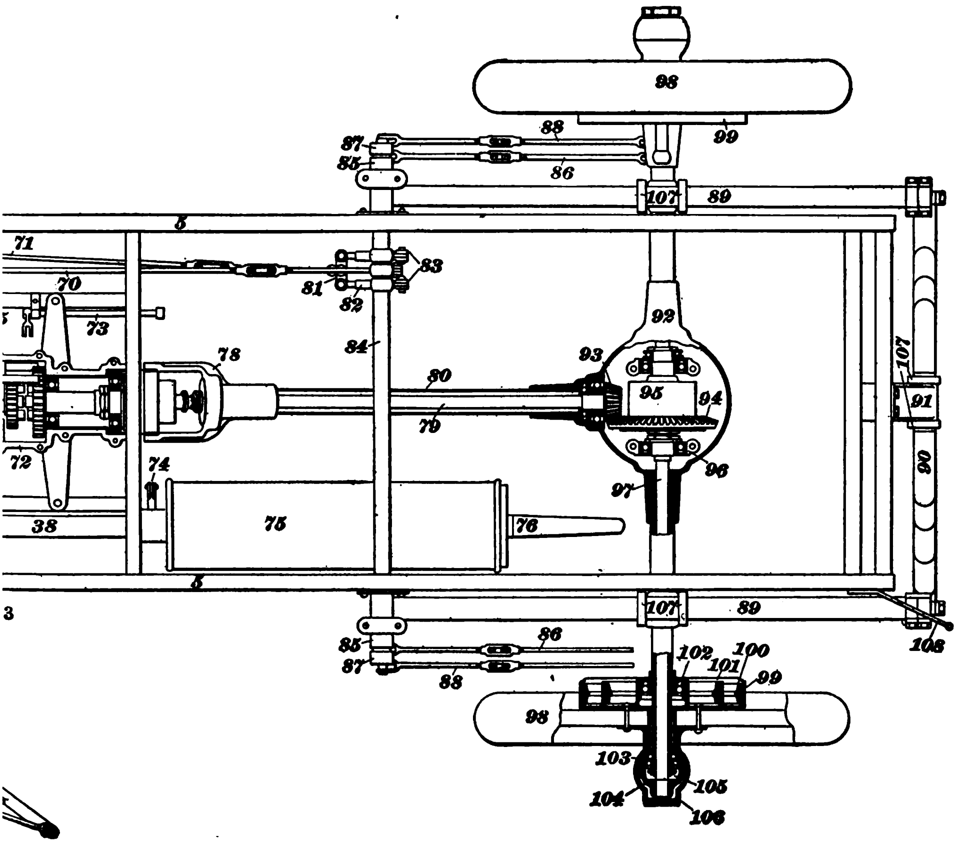


Fig. 4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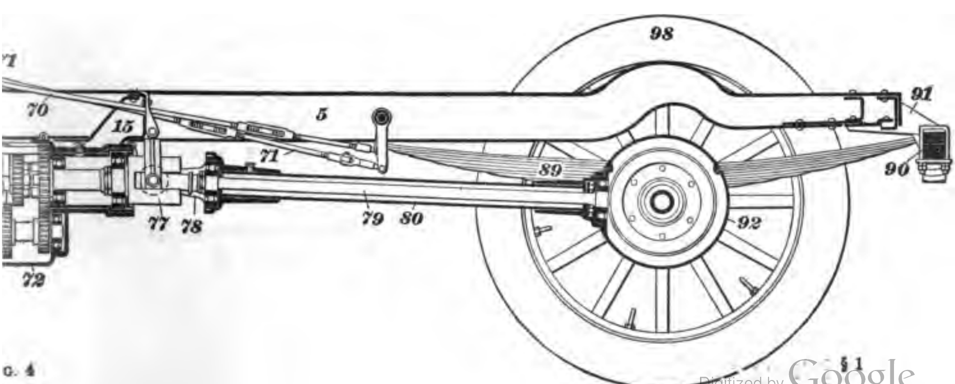
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G. 4

56, Induction coil for battery system of ignition
57, Switch for magneto
58, Foot-pedal for operating throttle
59, Foot-pedal for operating brake
60, Foot-pedal for operating clutch
61, Flywheel of engine
62, Cone clutch for transmitting power developed by engine through transmission to rear driving wheels
63, Arm of bell-crank lever attached to clutch-operating shaft and carrying special capscrews that engage the slotted clutch hub
64, Clutch hub
65, Clutch coupling block through which pass a short and a long clutch-coupling bolt, the latter passing through a sliding square
66, Transmission end of clutch coupling
67, Quadrant or ratchet bracket for control levers
68, Speed control or change-speed lever, by means of which the transmission gears are shifted so as to regulate the speed of travel to suit requirements
69, Emergency-brake lever
70, Hand-, or emergency-brake tension rod with turnbuckle
71, Foot-brake tension rod with turnbuckle
72, Case surrounding transmission gears and supported by the subframe *15*
73, Horizontal shaft with levers for operating cut-out
74, Muffler cut-out lever
75, Muffler
76, Tail-pipe of muffler
77, Main hardened-steel portion of universal joint at rear of transmission
78, Swivel hub supporting forward bearing for driving, or propeller, shaft
79, Driving, or propeller, shaft
80, Housing for driving, or propeller, shaft
81, Cross-bar of equalizing link for equalizing pressure on foot-brakes
82, Equalizing link rods to which are attached levers *83* on foot-brake tubes *84*, to which are also fastened levers *85* connected to the foot-brake tension rods *86*
83, Short levers fastened to and actuating foot-brake tubes, inside of which the hand-brake rod is carried
84, Foot-brake tubes to ends of which are fastened levers *85*
85, Levers to which foot-brake tension rods are attached
86, Foot-brake tension rods attached to actuating mechanism of large pair of internal expanding brakes on rear wheels
87, Levers on ends of hand-brake rod that passes through foot-brake tubes *84*
88, Hand-brake tension rods attached to small pair of internal expanding brakes on rear wheels
89, Half-elliptic rear springs
90, Cross, or platform, spring connected to the half-elliptic side springs *89*

91, Bracket for cross spring
92, Rear axle and differential housing
93, Driving pinion on rearward end of driving, or propeller, shaft
94, Bevel driving gear attached to one-half of driving axle
95, Case, or housing, for differential gears by means of which the other half of driving axle is driven
96, Annular ball bearings for differential, which includes the large bevel driving gear *94* and the smaller spur gears enclosed in case *95*
97, Live rear axle by means of which the power developed by the engine is transmitted to the rear road wheels
98, Rear wheels
99, Brake drum forming part of hub of rear wheels and having flanges for two internal expanding brakes
100, Large internal expanding brake band
101, Small internal expanding brake band
102, Inner ball bearing in hub of rear wheel
103, Outer ball bearing in wheel hub
104, Dog clutch fitting on squared end of axle and driving rear wheel
105, Locknuts for holding rear wheel on axle
106, Dust cap that prevents entrance of dust
107, Spring clips for holding rear springs in position, similar clips being used to hold front springs in place on front axle
108, Bracket for tail-lamp

9. In Fig. 5 is shown a plan view of the chassis of a small touring car equipped with a four-cylinder gasoline engine *a* and sliding-gear transmission *b*. From the speed-changing gears of the transmission the power is transmitted through a jointed propeller shaft *c* and bevel pinion and gear, enclosed in the differential housing at *d*, to a driving shaft enclosed in the rear axle tube *e*. Attached to the engine shaft is the flywheel *f* carrying a friction clutch, and just back of the clutch is a coupling *g* connecting the clutch with the speed-changing gears of the transmission. At *h* is a brake; at *i* and *j* are universal joints, which will be described later; and at *k* and *l* are hub brakes. In this transmission system the drive is *direct*, as it is called, in the high-speed gear. In the slow and intermediate gear positions, generally called the *first* and *second speeds*, the power is transmitted from a pinion on the engine shaft to a gear on a lay shaft, or jack-shaft, and

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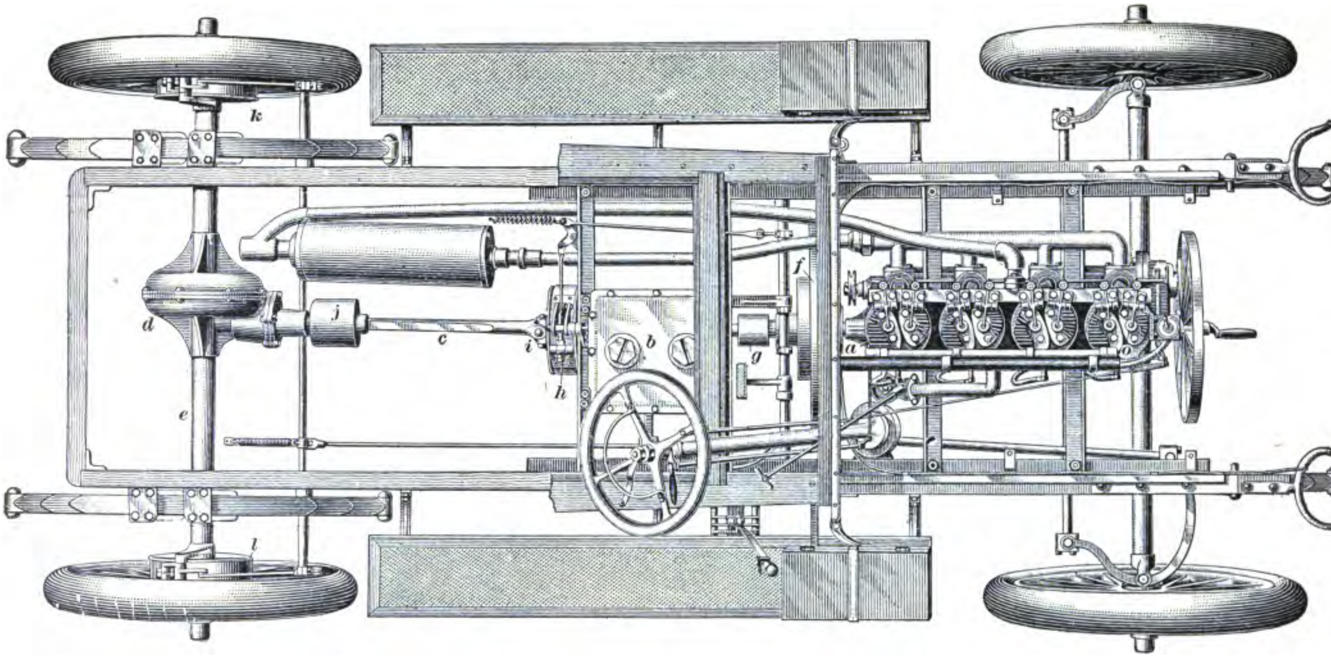


FIG. 5

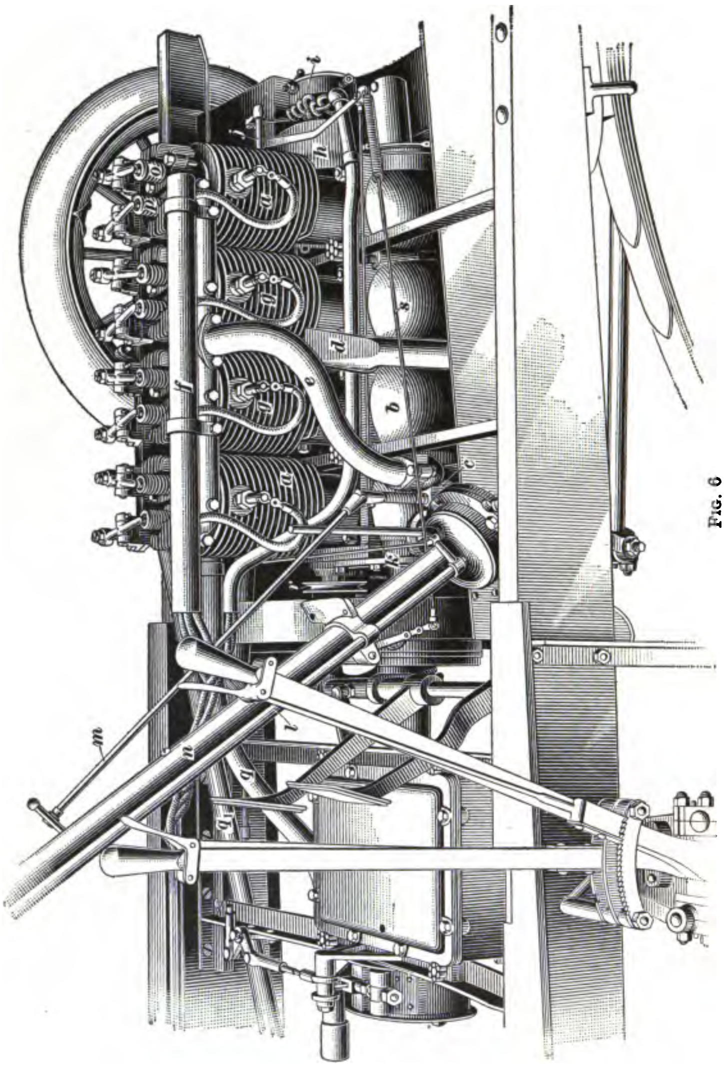


FIG. 6

from a pinion on the lay shaft back to a gear on the propeller shaft in line with the pinion first mentioned.

10. As shown in Fig. 6, the air-cooled cylinders *a* are bolted to a closed crank-case *b*, supported by two angle-iron cross-members of the frame on which the body of the car rests. Air is supplied to the carbureter *c* through the intake pipe *d*; while from the carbureter, the charge passes through the pipe *e* to the manifold, or supply pipe, for the four cylinders. Protection against accidental injury to the secondary cables is afforded by a fiber tube *f*, from openings in which the cables are led to the spark plugs *g*.

The governor on the cam-shaft is enclosed by the casing *h*, in front of which the spark timer *i* is located. The rocker-shaft *j*, controlling the spark time, is operated by the spark lever under the steering wheel. Adjustment of the proportions of the explosive mixture is effected by the rod *m*, operated by hand. The steering column is shown at *n*. The exhaust valve *o* and the inlet valve *p*, as well as auxiliary exhaust valves not shown, are mechanically operated by push rods actuated by cams mounted on a single cam-shaft. The auxiliary and main exhaust pipes are shown at q and q_1, respectively.

A pulley *r* for operating a mechanical oiling device is mounted on the end of the cam-shaft, as shown. A rod *s*, operated by the throttle lever, which is located under the steering wheel, as shown in Fig. 5, controls the position of the throttle. The circulation of air over the cylinders is assisted by the use of a fan, as shown in Fig. 5. The coil box and the mechanical oiler are mounted on the dash, the battery and tool boxes being carried on the forward ends of the running boards.

AUTOMOBILE RUNNING GEAR

WHEELS

11. Types of Motor-Vehicle Wheels.—Most automobiles are equipped with *wooden wheels* of the so-called *artillery type*, a form of wheel used on gun carriages and one capable of withstanding severe shocks under heavy loads. Early types of automobiles were equipped with *wire wheels*, that is, wheels having wire spokes. This type of wheel is at present returning to favor, several foreign manufacturing concerns having recently adopted it in preference to wooden artillery wheels. Some cars have been fitted with *all-steel artillery wheels* made up of stampings from sheet metal pressed to the required shape, and to a few machines have been fitted *all-metal wheels* of the disk type, a pair of plain metal disks pressed to a slightly conical shape being placed back to back and riveted together to form the complete wheel. Wheels of the artillery type are classified as *compression wheels*, and those having wire spokes are called *suspension wheels*.

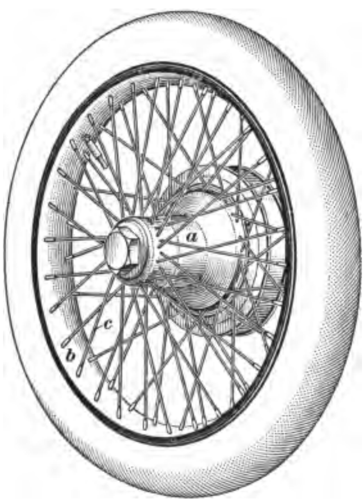


FIG. 7

12. Wire Wheels.—In proportion to their weight, **wire wheels** will sustain a heavier load and withstand a greater driving stress than will wooden wheels, but they are less resilient, that is, less elastic, and hence do not absorb and distribute road shocks so well as the wooden wheels. As shown in Fig. 7, a wire wheel has a hub *a*, a rim *b*, and spokes *c* that tie the hub and rim together, support the weight of the car and its occupants, and withstand whatever stresses are thrown

upon the wheel. To give the wheel lateral, or sidewise, stiffness, the spokes are splayed, or flared out; that is, one of each pair of spokes is run from one hub flange to the rim, the other spoke of each pair being carried to the opposite hub flange. In other words, one-half of the spokes on one side of the wheel are attached to the hub flange on the opposite side. In order that the wheel may withstand the driving, or propelling stress, the spokes are arranged tangentially as shown. The principle involved is illustrated by, and may be studied in connection with, the construction of an ordinary bicycle wheel. Wire wheels for automobile use, however, are not only heavier but the spokes are not spaced on the rim in the same way as in a bicycle wheel, there being a greater lateral, or sidewise, distance between the spokes at the rim end.

13. As shown in Fig. 7, which illustrates a modern type of wire wheel for motor vehicles, the sides of the wheel are not symmetrically splayed, the spokes on the outer side being flared out, or coned, so as to bring the wheel rim center line of a 34-inch wheel about $\frac{7}{8}$ inch inside the wheel hub center line. This construction gives the wheel greater strength to resist the sidewise stresses to which it is subjected when rounding a corner or when thrown against the curb because of skidding or careless driving. The spokes on the outer side are also made tangential to a smaller circle than that for the spokes on the inner side of the wheel. Thus, the inner spokes take most of the driving stresses, and the outer spokes resist most of the side stresses.

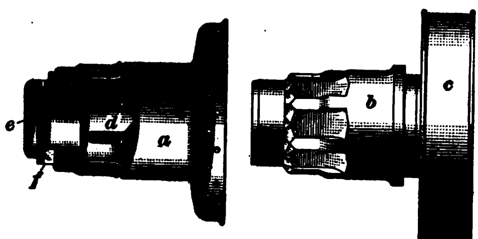


FIG. 8

14. Fig. 8 shows the construction of the hub of the wheel illustrated in Fig. 7. There is an outer hub *a* and an inner hub *b*, the latter being driven by the axle or by side chain and sprocket, as the case may be. In this case, the drive is

by means of a live axle, the brake drum *c*, flanged to receive an external contracting brake band, being located where the sprocket would be placed for a side-chain drive. At the outer end of the inner hub *b* slots are milled so as to form eight projections, or keys, that fit corresponding slots, or grooves, in the outer hub when the latter is put in place on the inner hub. The inner hub is provided with a triangular-shaped guiding, or pilot projection, *d* that serves to guide it into place, whatever may happen to be the position in which the wheel is slipped on. The hub cap *e* is screwed into place by means of a special spanner wrench that normally holds the locking pawl *f* out of engagement with a notch on the hub. When the wheel is brought securely home, a small lever on the spanner wrench is thrown over so as to release the pawl, which engages with the notch on the hub and thus locks the parts together. Failure to use the locking devices

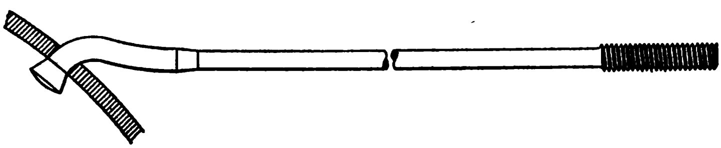


FIG. 9

is obviated by making the spanner wrench so that it cannot be removed until the pawl drops into the notch. The cap cannot back off, nor can it be removed until the pawl is depressed by the spanner.

15. The spokes of a wire wheel, of which there are about sixty for a 34-inch wheel, are of the form shown in Fig. 9. They are of 8 gauge (British) steel wire swaged to 10 gauge at the center. The head of the spoke, instead of being bent to an angle of 90°, as in bicycle wheels, is set at an angle of 45°, as shown. This increases the strength of the spoke and decreases the liability of breakage due to vibration. The spokes are threaded at the rim end to receive the threaded *nipples*, or long nuts, by means of which they are attached to the rim, the spokes being subjected to any desired tension in building up the wheel.

16. Wooden Wheels.—Compared with wire wheels, **wooden wheels** are more elastic, are much easier to clean, and are less subject to deterioration on account of rusting. The wooden wheels first applied to automobiles were of the

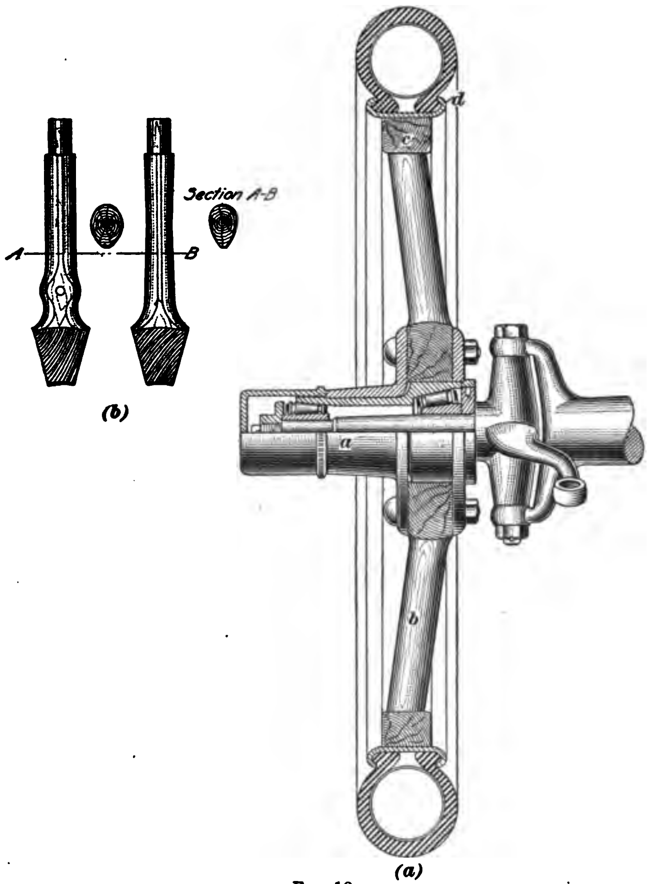
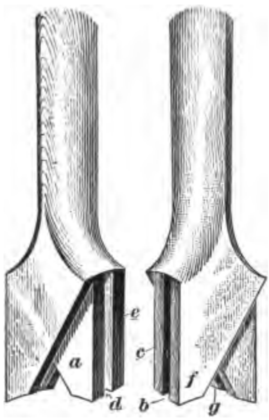


FIG. 10

staggered-spoke type, the spokes being set around the hub in two different circles, one at either side of the center line of the hub, and being splayed like those of wire wheels. Present-day wooden wheels for automobiles are of the *artillery type*, the spokes being set in a single circle around the hub, between

the flanges of which they are securely clamped by means of bolts. The artillery type of wooden wheel is easier to clean and repair and is stronger—because heavier—than the staggered-spoke type of wheel that it has replaced. The spokes of some artillery wheels are *dished*, that is, they are set inward at the hub as shown in Fig. 10, so as to give greater strength to resist lateral or sidewise stresses, as when turning corners. Other wheels have heavy spokes lying in a plane perpendicular to the longitudinal center line of the hub.

17. Fig. 10 (*a*) shows a sectional view that illustrates the construction of an artillery wheel and its roller-bearing hub



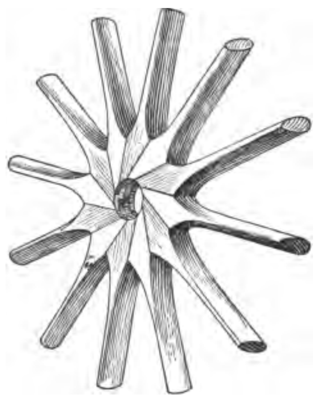


Fig. 11

on the spindle of the steering knuckle pivotally mounted in one of the yoke ends of the front axle. The wheel is made up of the hub *a*, the spokes *b*, the felloe *c*, and the steel rim *d*. In the process of manufacture, the rim, after expansion by being uniformly heated until hot enough to scorch paper, is pressed on over the felloe by means of a hydraulic press, the pressure required varying from 25 to 60 tons. All the wooden parts of the wheel are thus tied rigidly together, and the dishing of the spokes, which is clearly shown, provides for any change of tension on the spokes due to swelling of the wood when wet, or contraction thereof when extremely dry. Were it not for the dishing of the spokes, there would be a

tendency for them to draw away from the felloe and spread apart at the miter joints at the hub when dry, and the wheel would tend to warp out of true when wet.

Fig. 10 (*b*) shows the shape and section at *A–B* of one manufacturer's front-wheel spoke; also, a rear-wheel spoke to which the brake drum is attached by means of bolts passing through an enlarged portion of the spoke. The spokes are held to the hub by bolts that pass through them and through the hub flanges, as shown.

18. A very **popular** type of wooden wheel is constructed as shown in Fig. 11. The mitered joints at the hub end of the spokes are made to overlap by using the mortise-and-tenon principle in making the spokes. When the spokes are assembled, the tenon *a* fits into the mortise *b*, tenon *c* into mortise *d*, and the inner tenons *a* and *e* are overlapped by the outer tenons *f* and *g*. The spokes are thus interlocked so that they cannot work loose, and they support one another in a compact, true assemblage. The spokes are put together under pressure with the finest quality of glue, and the appearance of the spokes at the hub when assembled is as shown at the right in Fig. 11.

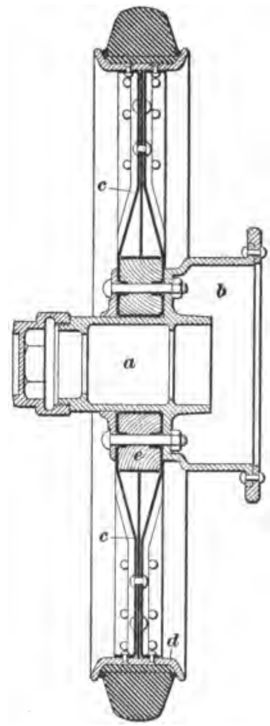


Fig. 12

19. Steel Wheels.—Except for use on motor trucks or other commercial vehicles, **steel wheels** are little used. The construction of one type of steel wheel is clearly shown in Fig. 12. The hub *a* and brake drum *b* is a one-piece steel casting, between the hub flanges of which are bolted the two stamped-steel plates, or disks, *c* that form the web of the wheel and in which there are outwardly projecting depressions that stiffen the plates and take

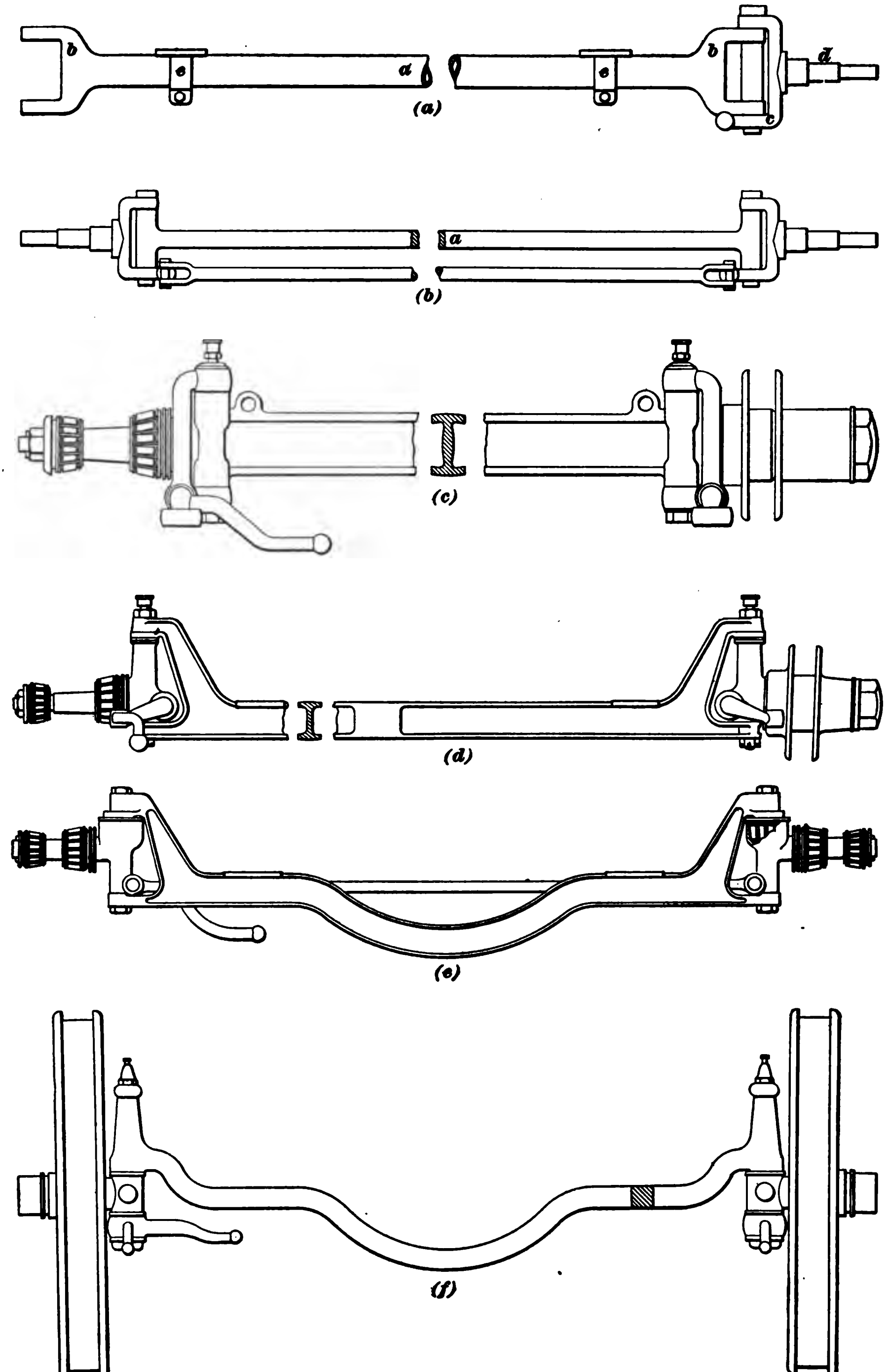


FIG. 13

the place of spokes. The webs *c* are riveted to the rim *d*, as shown, wooden rings *e* being interposed between the disks at the hub to give it greater stability.

20. Spring Wheels.—To obviate the use of pneumatic tires, the maintenance and first costs of which are high, and at the same time to secure the easy riding qualities of the pneumatic tire, many inventors have given a great deal of thought to the problem of producing commercially feasible **elastic,** or **spring, wheels.** Numberless designs have been produced, but spring wheels are not popular, having been applied to pleasure vehicles for experimental purposes only.

FRONT AXLES

21. Any shaft, or spindle, on which a wheel is mounted and with or on which it turns is an **axle.** The front axle of a horse-drawn vehicle is usually a solid, continuous cross bar, having at either end a spindle on which the wheel revolves, a so-called fifth wheel, lying in a horizontal plane above the center of the front axle, being employed with four-wheeled vehicles to permit of turning the front wheels. The weight of the vehicle is carried by the axles, which in turn are supported by the wheels. The front axle of an automobile, however, does not consist of a one-piece cross bar with a spindle on each end, but is made up of four parts, a bar carrying the spring seats, two knuckles carrying the spindles on which the wheels turn, and a cross-rod by which the two knuckles are tied together so as to move in unison.

22. Tubular Front Axles.—In Fig. 13 (*a*) is shown a **tubular front axle,** consisting of a seamless steel tube *a* to which are pinned and brazed or electrically welded the yoke ends *b*. The yokes *b* are designed to receive the steering knuckles *c* that carry the spindles *d* on which the wheels revolve. In some cases, the spring blocks, or seats, *e* were made adjustable, being clamped to the axle tube as shown. They were also sometimes brazed to the tubing. To impart strength, a truss rod attached to the yokes and having struts

bearing on the under side of the spring seats was sometimes used. Axles of this type, however, are not used so extensively now as formerly.

23. Solid Front Axles.—Axles in which the yokes form part of a one-piece cross-bar, as shown in Fig. 13 (*b*), (*c*), (*d*), (*e*), and (*f*), are known as **solid front axles.** It will be noticed on referring to Fig. 13 (*b*) and (*c*), however, that the yokes form part of the steering knuckles. The axle cross-bar *a*, Fig. 13 (*b*) is of square cross-section, as is also that shown in Fig. 13 (*f*). To give equal strength with less

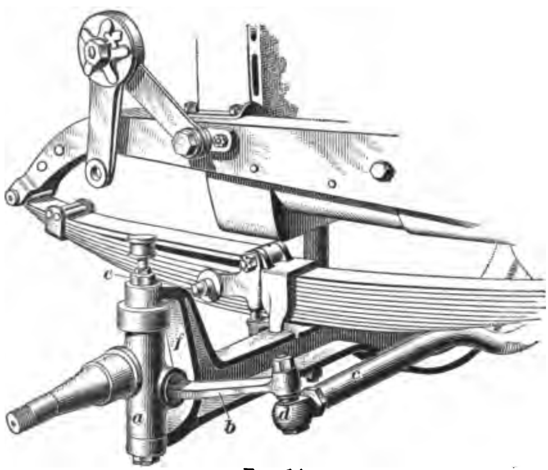


FIG. 14

weight most front-axle cross-bars are made of **I** cross-section, as shown in Fig. 13 (*c*), (*d*), and (*e*). The axles shown in (*a*), (*b*), (*c*), and (*d*) are called *straight axles*, and those in (*e*) and (*f*), *dropped axles*. Axles of a shape and style similar to that shown in Fig. 13 (*f*), but of **I**-beam section, are frequently cast of manganese bronze. The drop at the center tends to make the casting somewhat more elastic than it would be if straight, thus minimizing the effect of stresses due to road shocks. A front axle is said to be *cambered* when, according to the manner of supporting the steering-knuckle pins, it is bent upwards or downwards so as to bring the front wheels closer together at the bottom than at the top; or, in case the

wheels are vertically set, when a line passing downwards through the center of each of the steering-knuckle pins is inclined so as to meet the center line of the tire at the ground.

The axle shown in Fig. 13 (*f*) is cambered so as to make the center line of the steering-knuckle pins fall inside or touch the center line of the tire where it touches the ground, the object of thus canting the steering-knuckle pins being to make the steering easier.

24. Steering Knuckles.—The devices known as **steering knuckles** are made and applied in a variety of ways. Some of them are one-piece steel drop forgings, and others have separable distance-rod arms. Fig. 14 shows a steering knuckle *a* that has a separable arm *b* connected to the distance rod *c* by means of a ball-and-socket joint at *d*. The steering-knuckle pivot pin *e* passes through the yoke *f* and is prevented from coming out by a nut and cotter pin on the lower end. The steering knuckle shown in Fig. 14 is on the left-hand side of a car having the steering gear on the right-hand side. Fig. 15, in which the parts are lettered the same as those in Fig. 14, shows the right-hand steering knuckle, which is provided with an extra arm *g*, to which the reach rod from the steering gear is attached, so as to turn it and the left-hand knuckle on their respective pivot pins. The arm *b* and the distance rod *c* are connected by means of a yoke-and-pin joint instead of by a ball-and-socket joint.

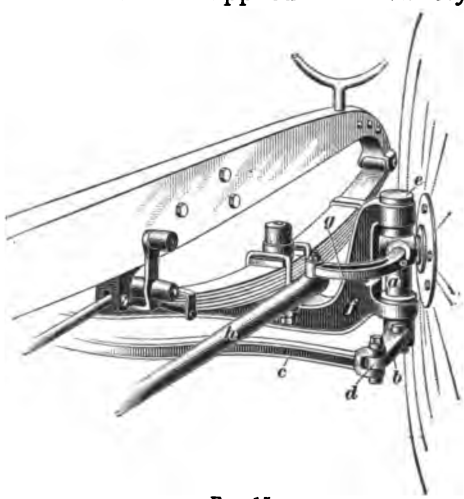


FIG. 15

25. One method of mounting a right-hand steering knuckle similar to those shown in Figs. 14 and 15 is illustrated in Fig. 16.

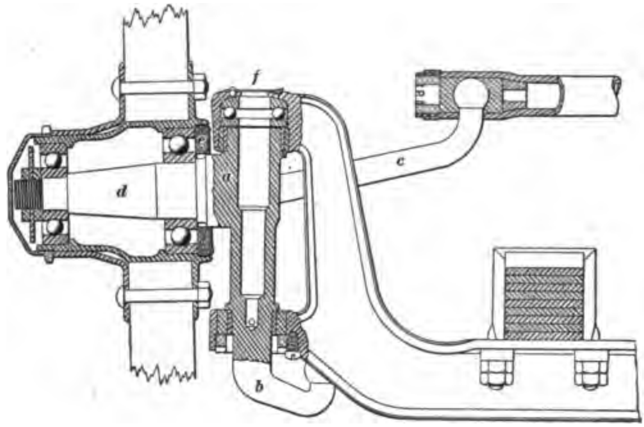


FIG. 16

Without going into minute detail, it will suffice to say that the steering knuckle *a* turns in renewable bushings at its upper and lower ends, a ball bearing being provided, as shown, to take the thrust at the upper end. The arm *b* is connected to the distance rod and the arm *c* to the steering-gear reach rod

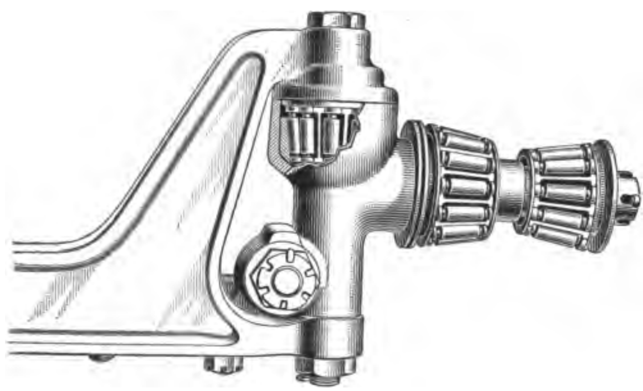


FIG. 17

by means of ball-and-socket joints. The road wheel runs on a pair of annular ball bearings mounted on the spindle *d*,

as shown. These ball bearings are protected from dust and dirt by the heavy armored felt dust ring, or cap, *e*, a swinging metal dust cap or shield *f* being placed over the knuckle thrust bearing, as shown.

A left-hand steering knuckle similarly mounted, but having a roller bearing at the upper end and roller wheel bearings on the spindle, is shown in Fig. 17. Figs. 14 to 17 illustrate what is known as the *Elliott type of steering knuckle.*

26. Another form of steering knuckle is shown in Fig. 18. In place of yokes at the ends of the front axle, there are heavy

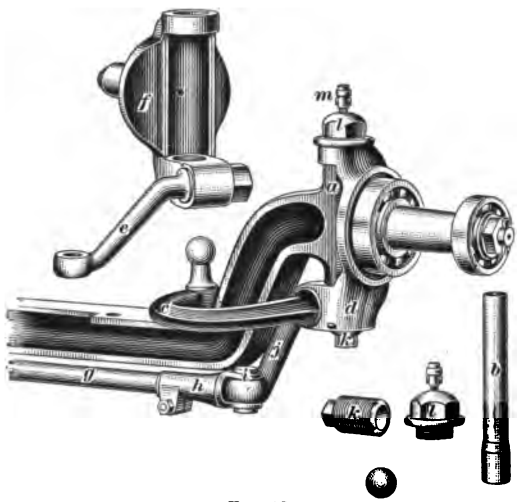


FIG. 18

T-shaped ends *a* through which are drilled holes to receive the pivot pins, one of which is shown at *b*. The steering knuckles are yoked as shown, the reach-rod arm *c* of the right-hand knuckle *d* and the distance-rod arm *e* of the left-hand knuckle *f* being made separable. The distance rod *g* is fitted with adjustable yoke ends *h*, the steering-knuckle arms being *pin-connected*, that is, pins, as *i*, serve to connect the arms *e* and *j* to the distance rod *g*. The pivot pin *b* rests on a ball in the threaded plug socket *k*, which is screwed into the lower yoke of the steering knuckle. It is covered at the top by the threaded cap *l*, which is screwed into the upper yoke and

carries a small lubricating oil cup *m*. The road wheel turns on two annular ball bearings mounted on the spindle, as shown. One of the objects of making the steering knuckle as shown in Fig. 18 is to get the wheel very close to the pivot pin in order to facilitate steering.

27. In what is known as the *Lemoine type of steering knuckle*, Fig. 19, the object just mentioned is very neatly accomplished. In this knuckle, the pivot pin is cambered, or set at an angle, so as to give quick sensitive steering, the wheel being brought as close as possible to the pivot pin.

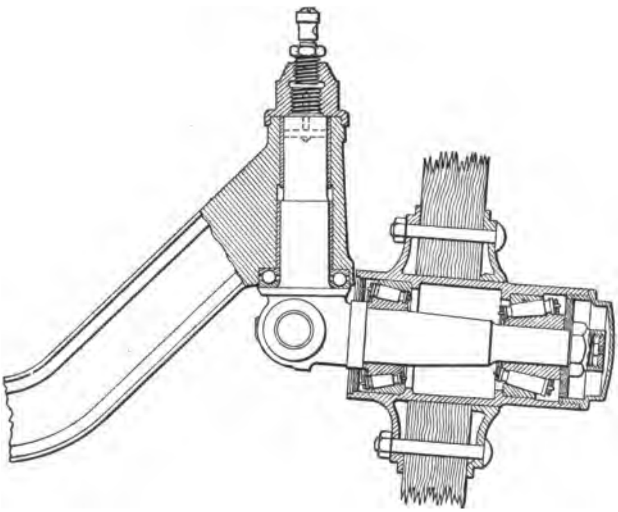


FIG. 19

As explained in connection with Fig. 13 (*f*), the pivot pin is set so that its projected center line will intersect the center line of the tire at the ground. A ball bearing at the base of the pin takes the thrust of the wheel, which in this case runs on roller bearings.

28. Generally speaking, the distance rod that connects the steering-knuckle arms is located behind the front axle, as indicated in Figs. 14 and 15, to protect it against damage that might occur from obstructions in the road, but it is also sometimes placed in front of the axle, as shown in Figs. 3 and 4.

On high-grade automobiles, freedom from binding at any point is secured by using ball-and-socket connections, such as are illustrated in Fig. 20, which is presented to show in a conventional way how the complete steering system of a modern automobile is arranged and how turning the steering wheel *a* to the right or the left causes a corresponding movement of the front wheels. When the wheel *a* is rotated, a worm at the lower end of the steering column *b* causes the segment of a worm-wheel with which it meshes to turn on its axle, thereby causing the arm *c* to move backwards or forwards, as the case may be. The motion of the reach rod *d* is transmitted to

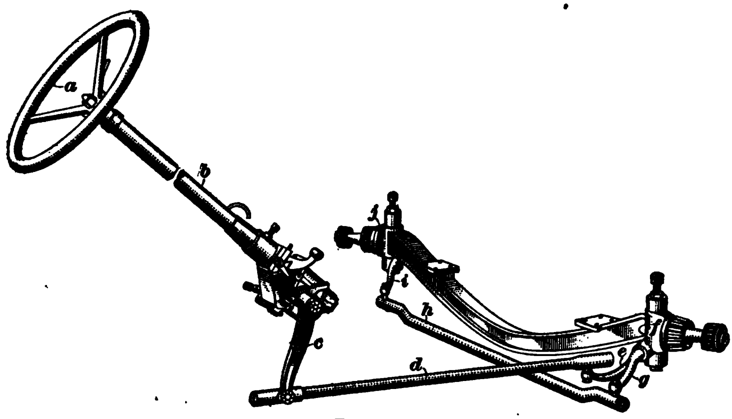


FIG. 20

the steering arm *e* of the right-hand steering knuckle *f*, and from the latter, through the knuckle arm *g* and distance rod *h*, to the arm *i* of the left-hand steering knuckle *j*. The two steering knuckles are thus made to move in unison to the right or the left in response to a corresponding movement of the steering wheel. When the wheel is turned to the right the reach rod *d* moves forwards, causing the front wheels to be swung around so that the car travels toward the right. Rotating the wheel in the opposite direction, causes the reach rod *d* to be drawn back, so as to turn the front wheels toward the left.

REAR AXLES AND HOUSINGS

29. Types of Rear Axles.—Rear axles are of two general types, namely, *live axles* and *dead axles*. A **live axle** is one that not only takes its proportionate part of the weight of the car and the occupants, but at the same time serves to drive the rear wheels and thus propel the vehicle. A **dead axle** is one that has no rotating parts, the wheels being driven by side chains from a countershaft, of which the differential, which is an essential element of the live type of axle, forms a part.

Classified according to the method by which the axle and attached wheels are driven, there are two kinds of live axles, namely, the *chain-drive rear axle* and the *shaft-drive rear axle*. Live rear axles may also be classified as *semifloating* and *full floating*.

Generally speaking, they are made up of three principal parts, namely, a *two-piece driving axle shaft*, a *differential*, and a *housing* that encloses the axle shaft and differential. That part of the housing which surrounds the axle shaft is sometimes called the *axle tube*, and to it are pinned and brazed or otherwise fastened the spring seats, or blocks, to which the rear springs are fastened by means of *spring clips*.

30. Chain-Driven Live Rear Axle.—The earliest form of live rear axle was of the chain-driven type, constructed on the same principles as that illustrated in Fig. 21, which shows, partly in section and partly in elevation, a *chain-driven live rear axle*. Besides carrying its proportion of the load, a live axle thus arranged must withstand the stresses due to the application of the power developed by the engine and utilized at the road wheels in propelling the car.

Both the weight and the driving stress are taken by the rotating live axle shaft, suitable bearings at the wheel and differential ends of each section of the axle being interposed between the shaft and the surrounding axle tube to reduce the frictional resistance to the turning of the axle shaft.

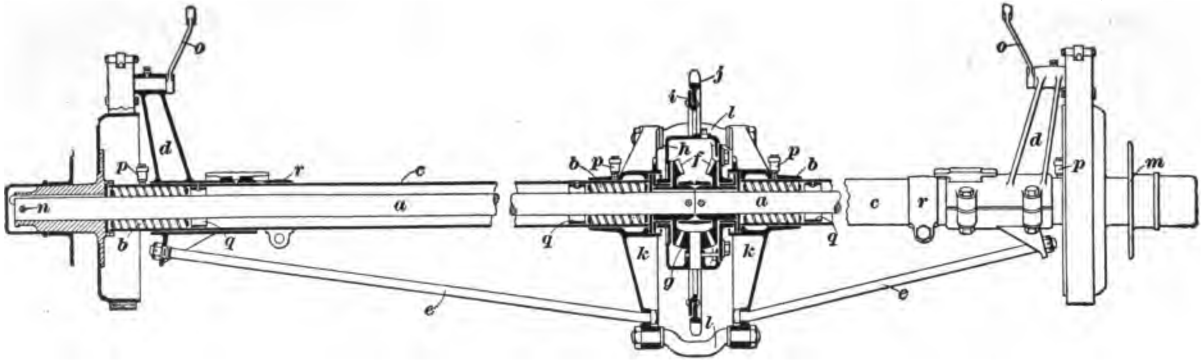


FIG. 21

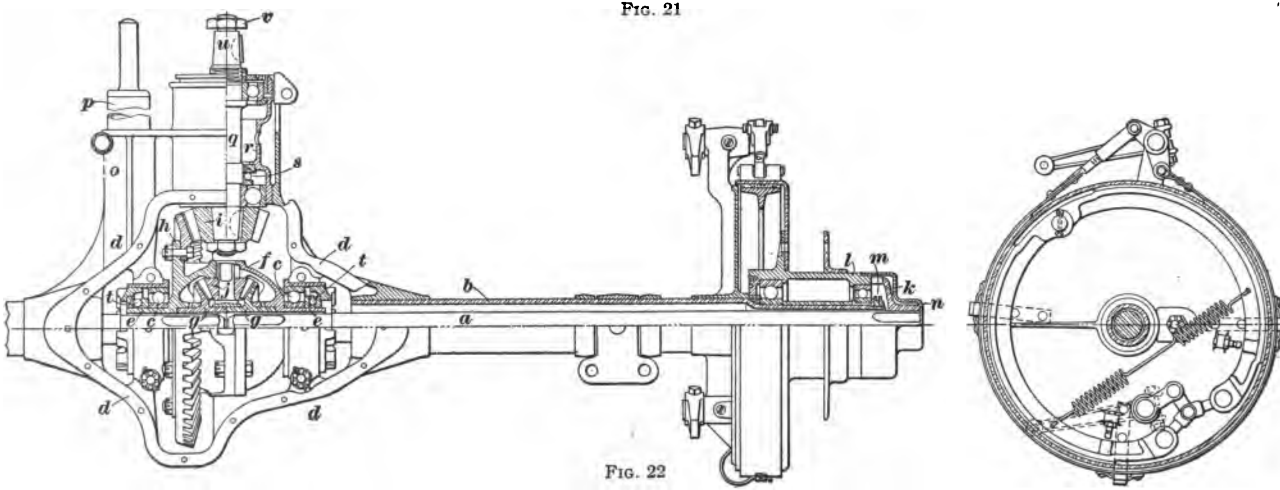


FIG. 22

Chain-driven live rear axles are at present used only on low-priced cars having single-cylinder or double-opposed horizontal engines and planetary transmissions, the full-floating and semifloating types of live rear axles being used on the higher-priced machines with vertical engines and sliding-gear transmissions.

31. As shown in Fig. 21, the two-piece live-axle shaft *a* turns on roller bearings *b* that lie between the shaft and the axle tube *c*, on which are mounted the rear spring and brake supports *d*. These supports are made in two parts and are clamped to the axle tube by bolts and nuts, as shown. The lower part of each support carries a lug through which passes the end of one of the truss rods *e* that help to support the weight of the differential and of the car. Keyed and pinned to the inner ends of the axle shaft are two bevel gears *f* that mesh with bevel pinions *g*, which permit the two parts of the shaft to rotate at different speeds and thus permit of turning corners without the dragging of the "off," or outside, wheel; that is, the wheel that travels on the larger curve of the turn. Surrounding the differential, or compensating, gears *f* and *g* is a casing, or housing, *h* having a rib or web *i* to which is riveted or bolted the *sprocket wheel* *j* by which the casing and pinion gears *g* attached to it are driven. The gears *f* move in unison only when the resistance to the turning is the same at each road wheel. The housing of the differential consists of a three-arm spider *k* at the inner end of each part of the axle tube. The spiders are joined by three distance pieces, or yokes, *l* held in place as shown by nuts that draw the spiders firmly against the shoulders on the yokes.

The wheel hubs *m* at the ends of the axle shaft are keyed to the shaft, as indicated, and are held in place by cross-pins *n*. The brake-actuating mechanism supported by *d* is operated by levers *o* connected by yoke-ended rods to the hand-operated brake lever at the driver's seat. The roller bearings *b*, which are supplied with oil by the small cups *p*, are held in place by cylindrical stops, or retainers, *q* riveted to the axle tube, as shown. The axle is held in proper position

relative to the frame of the car by means of *radius rods* attached to fittings *r* brazed to the axle tube.

32. Shaft-Driven Rear Axles.—As already stated, there are two types of shaft-driven rear axles known, respectively, as the full floating and semifloating. These terms do not refer to the method of driving, whether by shaft and bevel gears or by chain, but are descriptive of different methods of applying the wheel bearings so as entirely or partly to relieve the driving axle of the weight of the car.

33. The **full-floating rear axle** is so named because the outer wheel bearings, instead of being interposed between the live axle shaft *a* and the surrounding axle tube *b*, as in Fig. 21, are mounted outside of and are supported by the axle tube; also, as shown in Fig. 22, the bearings *c* at the differential end of the axle shaft instead of being mounted on the axle shaft, are supported by the differential housing *d*, the axle shaft passing loosely through the shank *e* of the internal housing *f* that surrounds the equalizing gears *g*. The two equalizing gears have their bearings in this internal housing, which on one side, as shown, forms a part of the large driving gear *h* that meshes with the driving pinion *i*. The squared ends of the axle shaft fit into square holes in the equalizing gears *g*. It is by means of these gears that the two halves of the axle shaft are driven in unison through the gears *j* when the turning resistance is the same at each road wheel.

34. Over the squared outer end of the axle shaft is placed a three-or-four-fingered dog, or clutch, *k* that meshes with a corresponding number of recesses in the wheel hub *l* so as to drive it when the axle turns. The wheel hub and bearings are held in place by nuts *m* on the threaded end of the axle tube, and the hub cap *n* prevents the clutch dog *k* from coming off the end of the axle shaft. The support for the brake-actuating mechanism, of which an end view is shown, is pinned and brazed to the axle tube.

At one side of the housing *d* and forming part of it is a hollow projection *o* bored out to receive the end of what is

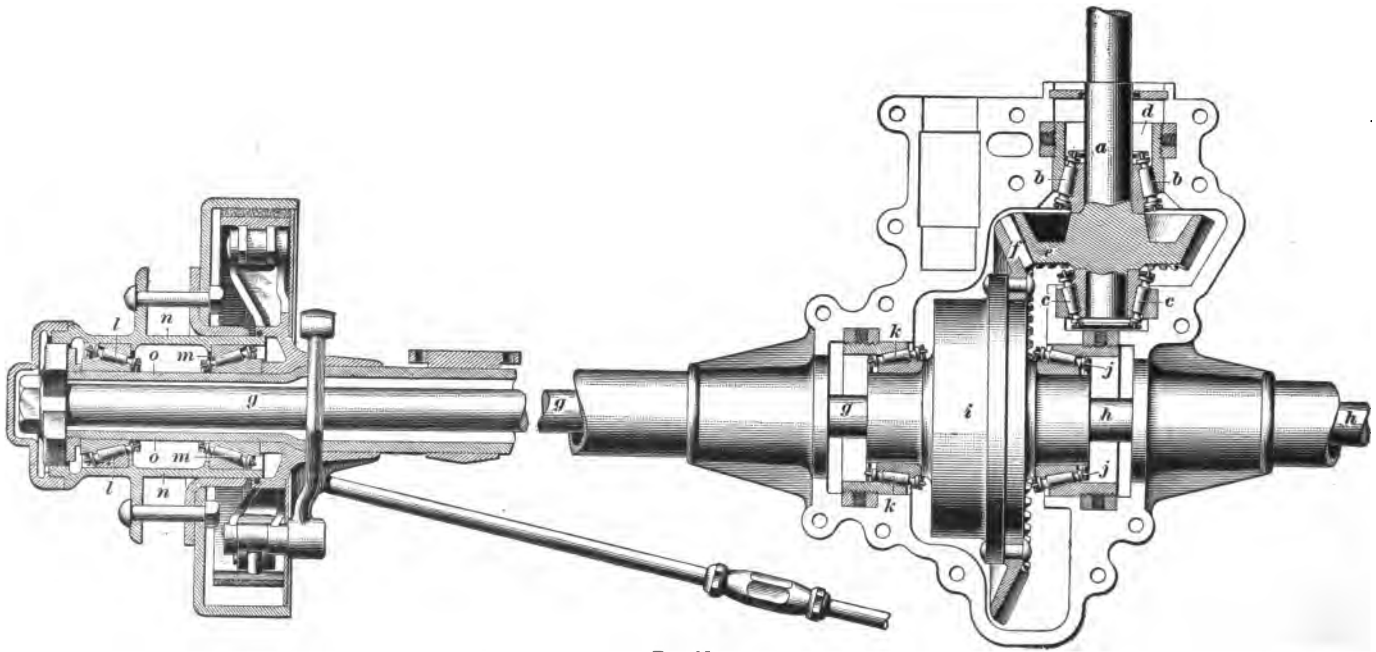


FIG. 23

known as a *torsion rod*. The housing is also slit along the side so as to serve as a clamp to hold the torsion rod *p* firmly in place. The torsion rod is provided to help overcome the torque, or turning stress, set up in the rear axle by the rotation of the bevel driving pinion *i*. If the torsion rod were not used, the tendency of the rear axle to turn around would have to be overcome entirely by the body springs. The forward end of the torsion rod is generally pivoted in a sliding block, sleeve, or some equivalent device to compensate for the movement of the body springs. The driving pinion shaft *q* runs on annular ball bearings mounted in a shell, or sleeve, *r*. This sleeve also carries a ball thrust bearing *s* to take the end thrust on the driving pinion. The end thrust at the differential bearings is taken by the thrust bearings *t*. To the tapered shank *u* of the driving pinion shaft *q* is keyed the cross of the universal joint (not shown) at one end of the propeller shaft that serves to make the connection between the transmission and the rear axle. The nut *v* holds the cross in place on the tapered shank *u*.

35. A top view of the central portion, partly in horizontal section, together with a vertical section of the wheel end, of another full-floating axle with tapered roller bearings is shown in Fig. 23. The driving pinion shaft *a* is supported by conical roller bearings *b* and *c*, the former in a threaded take-up cup *d*, on each side of the bevel pinion *e*, which meshes with the large differential gear *f* and drives it. The gear *f* drives the shafts *g* and *h* through the equalizing gears within the internal housing *i*. Wear on the bearings *j* and *k* is taken up, as with bearing *b*, by adjusting the threaded cups against which the rollers bear, the conical shape of the rollers and of the races taking care of the end thrust on all the parts. The bearings *l* and *m* of the wheel hub *n* are mounted on the end of the axle tube *o*. This tube therefore takes all the weight of the vehicle, the axle *g* being subjected to the driving stress only. The wheels are driven by three-fingered clutches that fit into the recesses provided for them in the wheel hub, and are held in place by nuts on the end of the axle shaft. Part of the

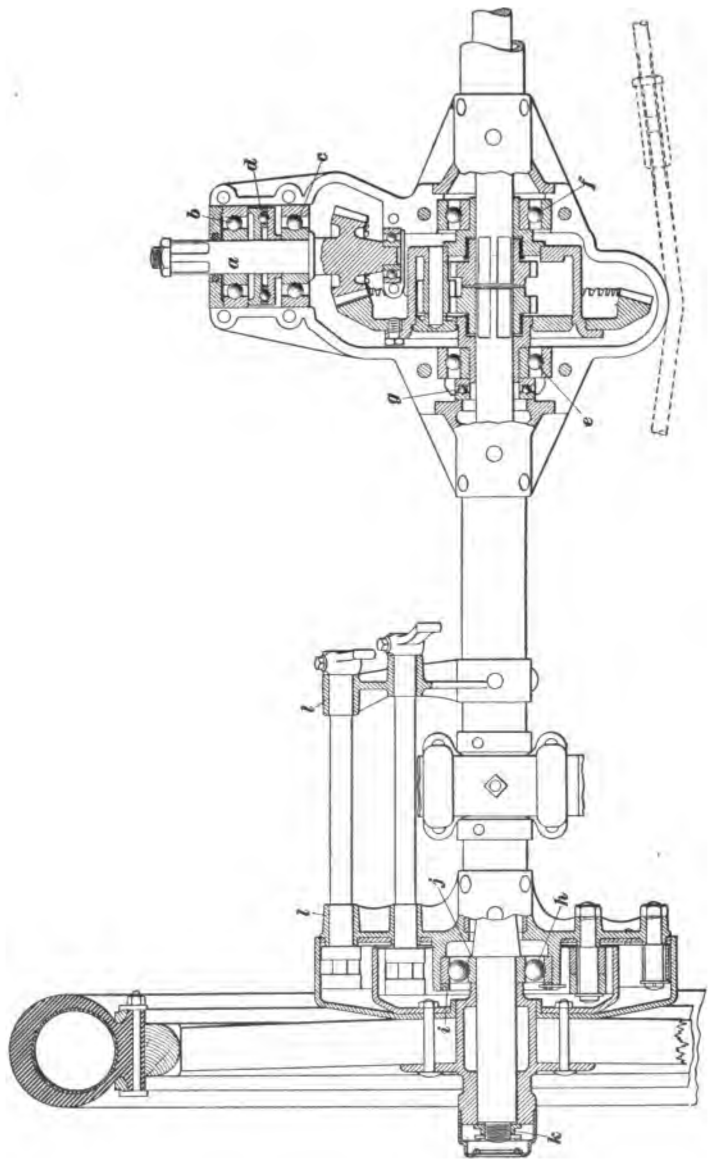


FIG. 24

weight of the differential is supported, and the effects of road shocks partly eliminated, by the truss rod shown in connection with the vertical section at the left, a turnbuckle being provided for adjusting it.

36. One form of **semifloating rear axle** is shown in Fig. 24. The principal difference between this axle and the full-floating type shown in Figs. 22 and 23 is that the bearings at the wheel end of the axle shaft are mounted directly on the shaft instead of on the axle tube. The inner bearings are arranged as in the full-floating type of axle. Generally speaking, this arrangement is characteristic of axles of the semifloating type. The driving pinion shaft *a* is supported at its inner end, as in Fig. 23, but on a ball bearing instead of a roller bearing. Any kind of bearing may be used with axles of the semifloating type. The shaft runs on annular ball bearings *b* and *c*, the outward thrust on the pinion shaft being taken by the thrust bearing *d*. The casing that surrounds and supports the equalizing gears and to which the large differential driving gear is attached by capscrews, as shown, is supported on annular bearings *e* and *f* mounted in the differential housing, as in Figs. 22 and 23. The end thrust on the differential driving gear is taken by the thrust bearing *g*. The differential is of the spur-gear type; that is, spur gears and pinions are used instead of the bevel compensating, or equalizing, gears *g* and bevel pinions *j* used in the axle shown in Fig. 22.

The road wheels are supported on annular ball bearings, as *h*. These bearings are mounted directly on the shaft, as shown, and fit into a machined recess in a steel casting that is pinned and brazed at the end of the axle tube. A threaded ring *i* holds the wheel bearing *h* in place, and this bearing bears against a shoulder *j* on the axle shaft and thus prevents the shaft from coming out. The wheels are mounted on the squared ends of the axle shaft and are held in place by nuts *k*, which in turn are secured by cotter pins and covered by the hub caps. The supporting members *l* for the brake-actuating mechanism are castings pinned to the axle tube, and lie in a horizontal plane. Two internal expanding brakes are provided.

37. To camber rear wheels, that is, to bring them nearer together at the bottom than at the top, the axle must be arched, and to do this some kind of universal joint must be

Fig. 25

placed in the axle shaft at each side of the differential. In one case, the type of joint shown in Fig. 25 is employed. To the inner squared end of each of the two halves of the axle shaft, as *a*, is fitted a male jaw clutch *b* that resembles a spur gear. This clutch meshes with a female jaw *c*—very much like an internal gear—on the end of a short shaft *d*, the squared end of which fits into one of the equalizing gears, just as does the inner squared end of the axle shaft shown in Fig. 24.

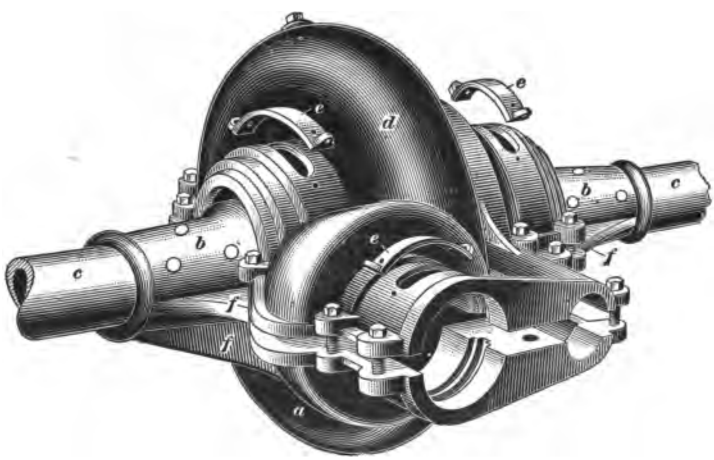


Fig. 26

38. Axle Housings.—On chain-driven live axles, the open type of housing, such as is shown in Fig. 21, must necessarily be employed in order to give the requisite strength

by affording widely separated points of support for the axle-tube spiders and to permit a chain drive to be used. With shaft-driven rear axles, however, the housing is entirely closed. The housing for the axle illustrated in Fig. 23 is shown in Fig. 26. The lower part of the housing *a* is pinned and brazed at *b* to the axle tubes *c*, as indicated. The housing is divided horizontally, the upper part *d* being fastened to the lower part with capscrews. Removable plates *e* are provided in the upper half of the casing so that access may be had to the bearings when it is necessary to adjust them. The figure shows the housing as it appears when viewed from a point at one side near the front end of the car, the upper half of the housing having been lifted about an inch and the pinion, axle shaft, and attached gearing removed. The strength of the housing

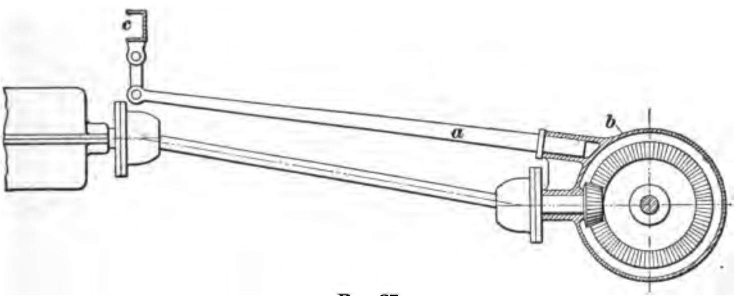


FIG. 27

is increased considerably by the use of webs *f*. Some housings have cover-plates vertically disposed, so that the differential is accessible from the rear of the car.

39. Torsion Rods.—The rear axle of a shaft-driven car has a tendency to rotate in a direction opposite that in which the wheels are rotating when the engine is driving the car. The turning effort tending to rotate the axle is equal to that which drives the traction wheels. When the clutch is thrown out and the hub brakes are applied, the wheels tend to drag the axle around with them. The turning effort then acting on the axle is equal to that resisting the rotation of the road wheels. This applies to both shaft drives and chain drives, whether the latter are of the single, or center, chain type, or

of the double, or side, chain type. Unless some other means is provided to resist the tendency of the axle to rotate, the springs of the car and their connections to the axle prevent the axle from rotating. Some cars have such means provided.

40. One method of applying a **torsion rod,** which is the means usually provided to resist the tendency of the rear axle to rotate, is shown in Fig. 27. The rear end of the torsion rod *a* is rigidly attached to the differential gear-case *b*, which forms part of the rear axle. The forward end of the torsion rod is connected to the frame *c* of the car by means of a link and pins. The link-and-pin connection allows the axle free play up and down, and also forward and backward to some extent, on account of spring action, while at the same time it resists the tendency of the axle to rotate.

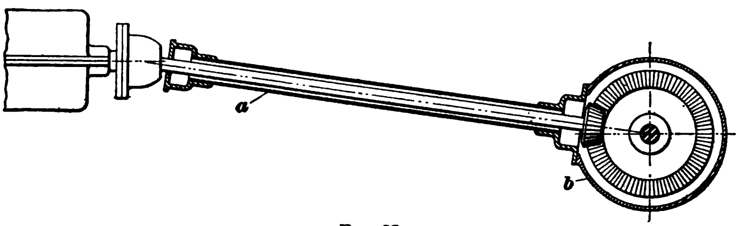


FIG. 28

41. Another form of torsion rod, which is really a tube, is shown in Fig. 28. The tube *a* encloses the propeller shaft, and its rear end is rigidly attached to the differential gear-case *b*. The forward end of the *torsion tube* is supported by the corresponding part of the propeller shaft. Sometimes the forward end of the torsion tube is connected to the change-speed gear-case by a joint suitable to allow for the motion of the rear axle. This latter form has the advantage of completely enclosing the universal joints so as to retain the lubricant and exclude dust.

It may be noted that the construction in Fig. 28 has only one universal joint between two shafts, which are not in line. Because this form of propeller shaft and torsion tube introduces the disadvantage of a variable speed, it should be used only when there is no angle, or only a very slight angle,

between the propeller shaft and the change-speed gear-shaft to which it is connected.

42. Radius Rods.—In order to keep the rear axle always at right angles to the frame, or, in other words, to the chain or the shaft by which the road wheels are driven, what are known as **radius rods** are used. These rods, one on each side of the frame of the car, are usually provided with two yoke ends, one of which is pinned to a lug carried by the spring-seat forging or by a special fitting, as *r*, Fig. 21, on the axle tube, and the other to a lug on the frame, permitting the axle to move freely up and down, but maintaining equal distances to the ends of the axle. In chain-driven cars equipped with swivel spring seats, the radius rods also serve as take-up rods for adjusting the distance between the engine sprocket and the differential sprocket. These rods are equipped with turnbuckles that permit of taking up any undue slack caused by wear. When turnbuckles are not used, the yoke ends are made longer and are threaded, so that the chain tension may be varied by screwing up or unscrewing the yoke ends.

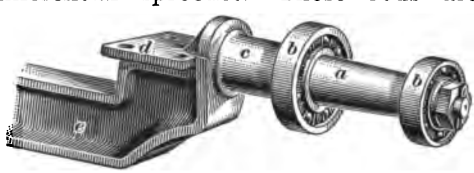


FIG. 29

With some shaft-driven cars the so-called torsion tube that surrounds the propeller shaft, as shown in Figs. 3 and 4, or the torsion rod used with the rear axles shown in Figs. 23 and 24, not only serves to take care of the torsional stress produced by the driving pinion, but takes the place of the radius rods used on other cars. In some cases, as in Fig. 5, neither a torsion rod nor radius rods are used, the driving stress being taken by the springs alone.

43. Dead Axles.—Some **dead axles** are perfectly straight and of rectangular cross-section, but as a rule the axle is dropped between the spring seats, as shown in Fig. 29, and is of I-beam section. As its name would indicate, the dead axle is stationary, the wheels revolving on the spindles

at the ends of the axle. On the wheel spindle *a*, Fig. 29, are shown the two annular ball bearings *b* of the wheel, beyond which on the spindle at *c* is mounted the radius rod and the braking mechanism. The spring seats *d* form an integral part of the axle forging *e*.

44. Dead axles are used only with the double-chain type of drive. Each of the rear wheels is provided with a large sprocket *a*, Fig. 30, which in this case forms part of a drum that is riveted to the webbed wheel hub *b*, as shown. This

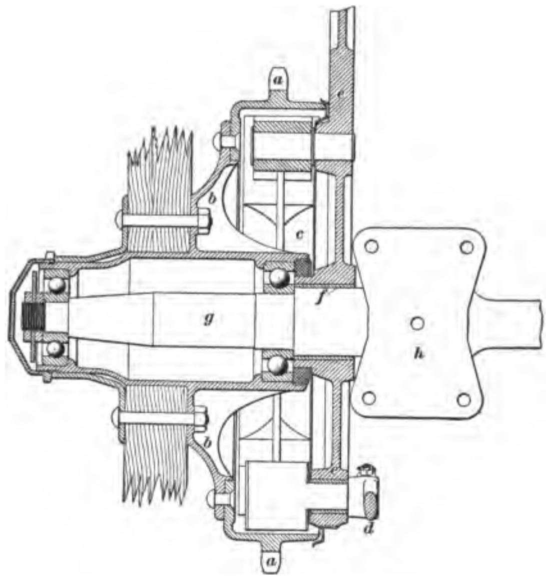


FIG. 30

drum provides braking surface for the internal expanding brake *c*, which is actuated by the brake lever *d*. The bearing pin for the latter, as well as for the brake shoes, is supported, as indicated, by the radius rod *e*, which is free to turn in a large bushing *f* on the spindle *g*, just beyond the spring seat *h*.

45. In Fig. 31 is shown another form of combined sprocket and brake drum *a*. In this case the device is bolted to the spokes of the wheel instead of to the wheel hub, and it provides

braking surface for the double-acting internal expanding brake shoes *b* that are normally held out of engagement with the drum by the springs *c*. A chain passing over the sprocket *d*

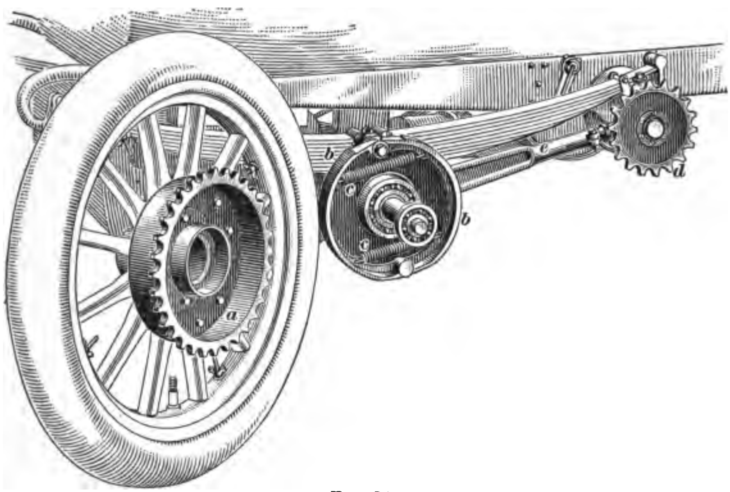


FIG. 31

on the end of a countershaft and around the sprocket *a* transmits to the wheel the power developed by the engine, the adjustable radius rod *e* keeping the distance between the sprocket centers alike on both sides of the car. To protect the chain and sprockets from dust and dirt, they are in some cars covered with a light, grease-tight case, or housing, that is arranged to permit of movement of the rear axle without affecting the tightness of the case.

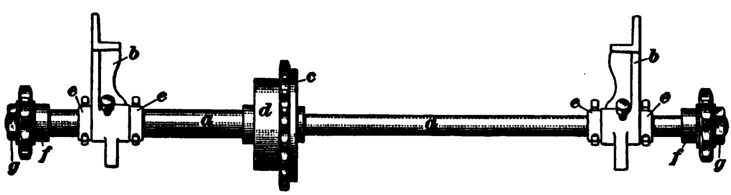


FIG. 32

46. Chain-Drive Countershafts.—With the side-chain type of drive, in order that the wheels on the dead rear axle may run at different speeds when turning corners, it is

necessary to use a countershaft embodying a differential. The countershaft may be driven by a chain and sprocket, as in Fig. 32, or by a shaft and bevel gears as in Fig. 33.

47. Fig. 32 shows a type of countershaft especially adapted for use in conjunction with horizontal double-opposed engines and the so-called center chain drive used on motor buggies. The two-piece live shaft *a* is supported in bearings in the brackets *b* attached to the side members of the frame, and the differential driving sprocket *c* is mounted on the

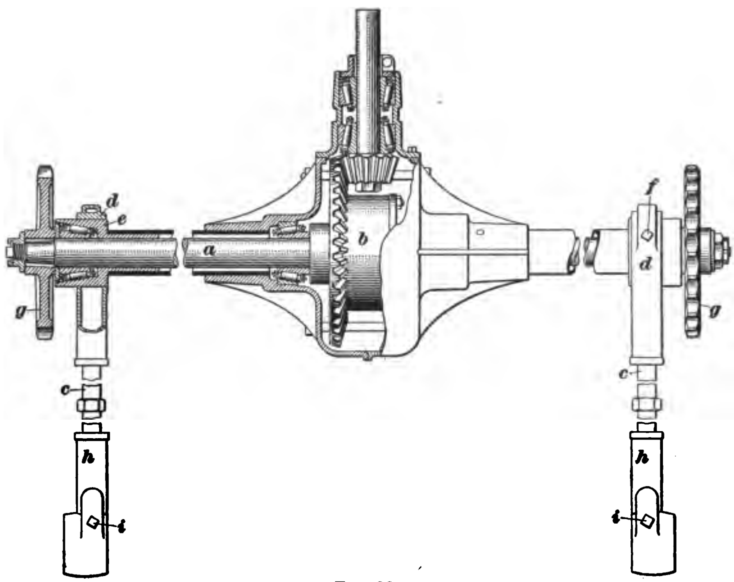


Fig. 33

housing, or case, *d* containing the compensating, or equalizing, gears on the inner ends of the two pieces of the shaft *a*. Sidewise, or end, movement of this shaft is prevented by collars *e* located on each side of the bearing supports *b*. The collars are held in place by setscrews, while the sprockets *f* are held on by nuts *g* on the outer ends of the countershaft.

48. In Fig. 33 is shown a shaft-driven countershaft constructed on exactly the same principle as a live rear axle. Sprockets instead of wheels are fixed to the outer ends of the

live axle *a*, on whose inner end are equalizing gears enclosed by the internal housing *b*. Adjustable radius rods *c*, whose ends *d* encircle the outer race *e* of the wheel bearings and are held to them by setscrews *f*, serve to keep the countershaft

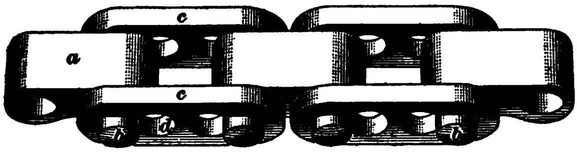


FIG. 34

parallel with the rear axle; or, in other words, to keep the sprockets *g* on the countershaft in line with those on the rear axle. On the latter are sleeve bearings that pass through the rearward ends *h* of the radius rods. Setscrews *i* serve to hold the rear-axle sleeve bearings firmly in the rod ends. When the relative positions of the countershaft and rear axle change, as when the rear axle moves up and down while the car is traveling over rough roads, the rod-end bearings oscillate on the countershaft and rear axle.

49. Automobile Chains.—There are two common types of automobile chains known as the *block chain* and the *roller chain*. As shown in Fig. 34, the **block chain** consists of steel blocks *a* held by pins *b* between hardened side links *c*, the distance from center to center of the links being called the *pitch* of the chain. The pins of this type of chain permit of

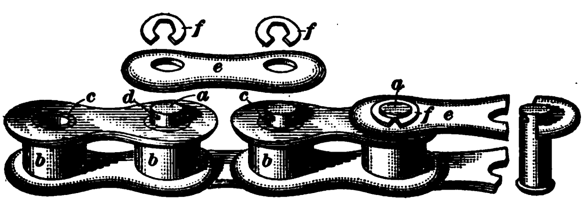
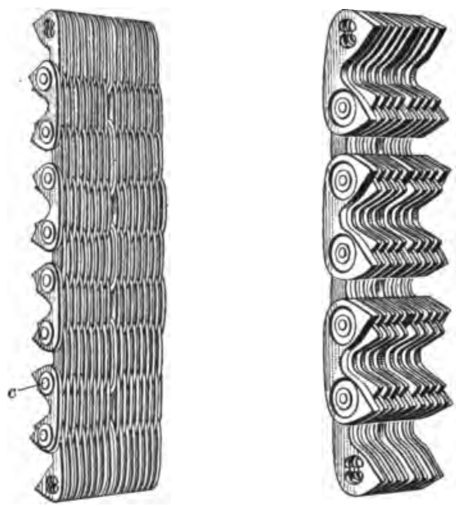


FIG. 35

detaching the chain at any link. The pin is flattened where it draws into a slot that is somewhat smaller than the diameter of the openings *d* in the side links through which the pins are introduced.

50. Fig. 35 shows a piece of **roller chain** at the point where the so-called *master link* that permits of detaching the chain is inserted. As the name would indicate, the roller type of chain consists of pins *a* that carry rollers *b*, which rotate on bushings *c* that surround and turn on the pins *a*. Near the end of each of the two pins of the master link are milled two slots *d*, into which, after the side link *e* is slipped on, the clips, or fasteners, *f* are forced and closed by a pair of flat-nose pliers. These clips may be removed by means of a screw-driver or with a special tool provided by the chain manufacturers. The pins, or studs are knurled at the neck where they pass through the links, into which they are forced under pressure.



51. A special type of chain for use on automobiles with the so-called center-chain drive is shown in Fig. 36. It is made up of stamped steel links *a* mounted on bushings *b*, through which are passed shouldered steel pins *c*. Opposite the shouldered ends of the pins are washers that hold the link pins in place. The two-piece bushings *b* are prevented from turning by inwardly extending projections on the links *a*. The rear sprocket for use with this chain is flanged on both sides to keep the chain in place, while the forward sprocket, which resembles a gear, is made wider than the chain to permit of a considerable amount of side play.

Fig. 36

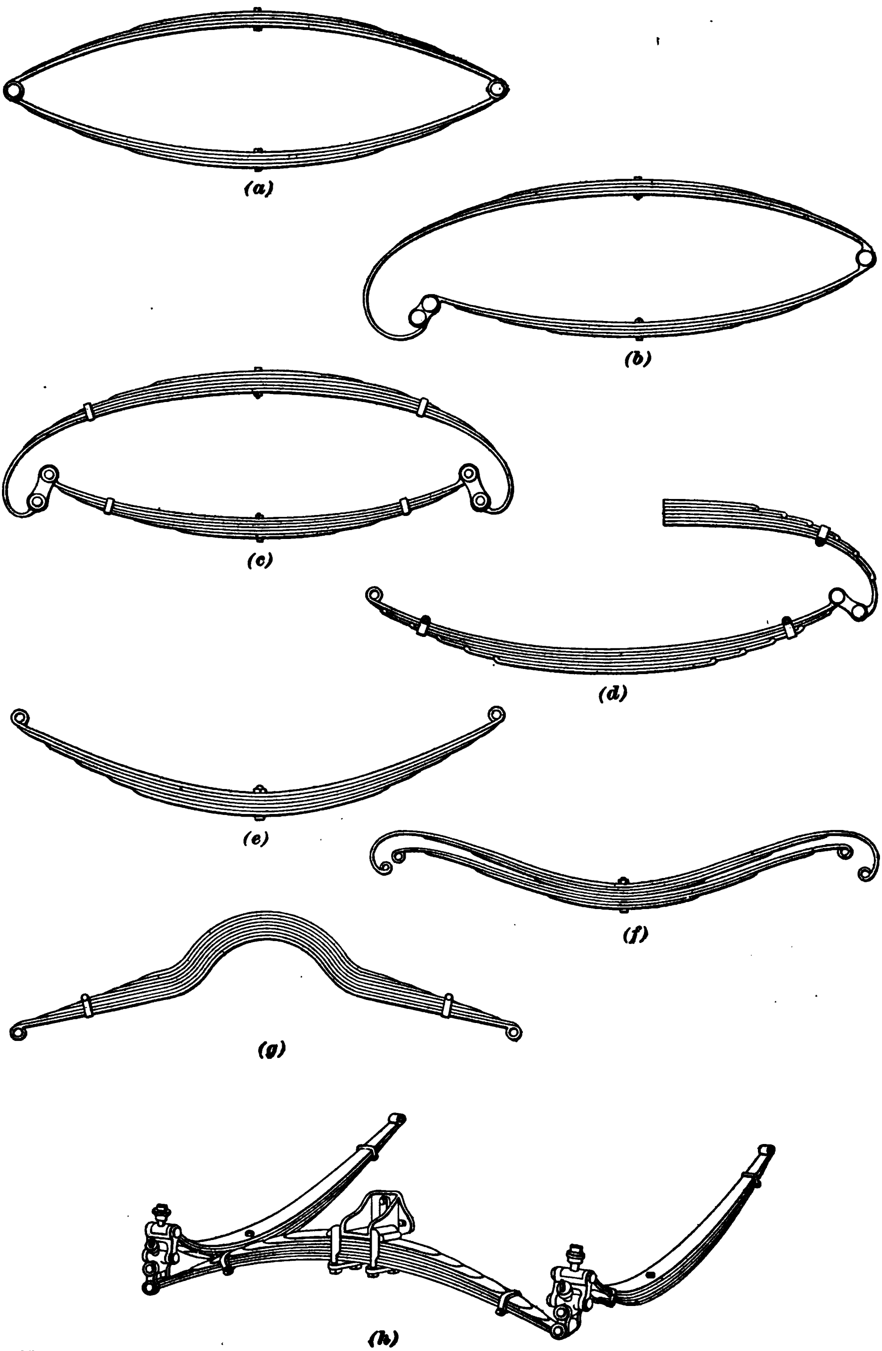


Fig. 37

AUTOMOBILE SPRINGS

52. Automobiles are equipped with various types of springs, examples of which are presented in Fig. 37. All are made up of long, comparatively thin and narrow curved steel plates, laminations, or *leaves* of different lengths. The leaves are usually held together by a bolt at the center, and the shorter ones are prevented from moving sidewise by small lips at their ends or by clips that pass around them, as shown in Fig. 37 (*c*), (*d*), (*g*), and (*h*). The springs minimize the effect of road shocks on the occupants of the car, as well as on the machinery.

53. There are three types of **full-elliptic spring.** In Fig. 37, (*a*) shows the common *button-head type*, (*b*) the *single-scroll type*, and (*c*) the *double-scroll type*. The upper and lower halves of the spring are held together by bolts or pins passing through eyes or through links at the ends of the spring. In (*d*) is shown the much used and very popular **three-quarter-elliptic spring,** which may be said to represent a cross between the full-elliptic spring and the more frequently used **half-elliptic spring** (*e*), of which a modified form, known as a *double semielliptic spring*, is shown at (*f*). All the springs just mentioned are arranged lengthwise of the vehicle, but the frame and all that it carries is sometimes supported at the front and rear on inverted half-elliptic **cross-springs** that run crosswise of the vehicle. One type of cross-spring is shown shackled to the steel castings on the ends of the rear-axle tube in (*g*). The **platform spring** (*h*) may be said to be made up of two regular half-elliptic springs shackled to a third half-elliptic inverted cross-spring.

FRAMES

54. Types of Frames.—There are three types of frames for supporting the body and machinery of automobiles, namely, the *armored-wood frame*, which consists of wooden sills strengthened by steel plates or entirely surrounded by a metal casing, or armor; the *angle-iron frame*, which is made up

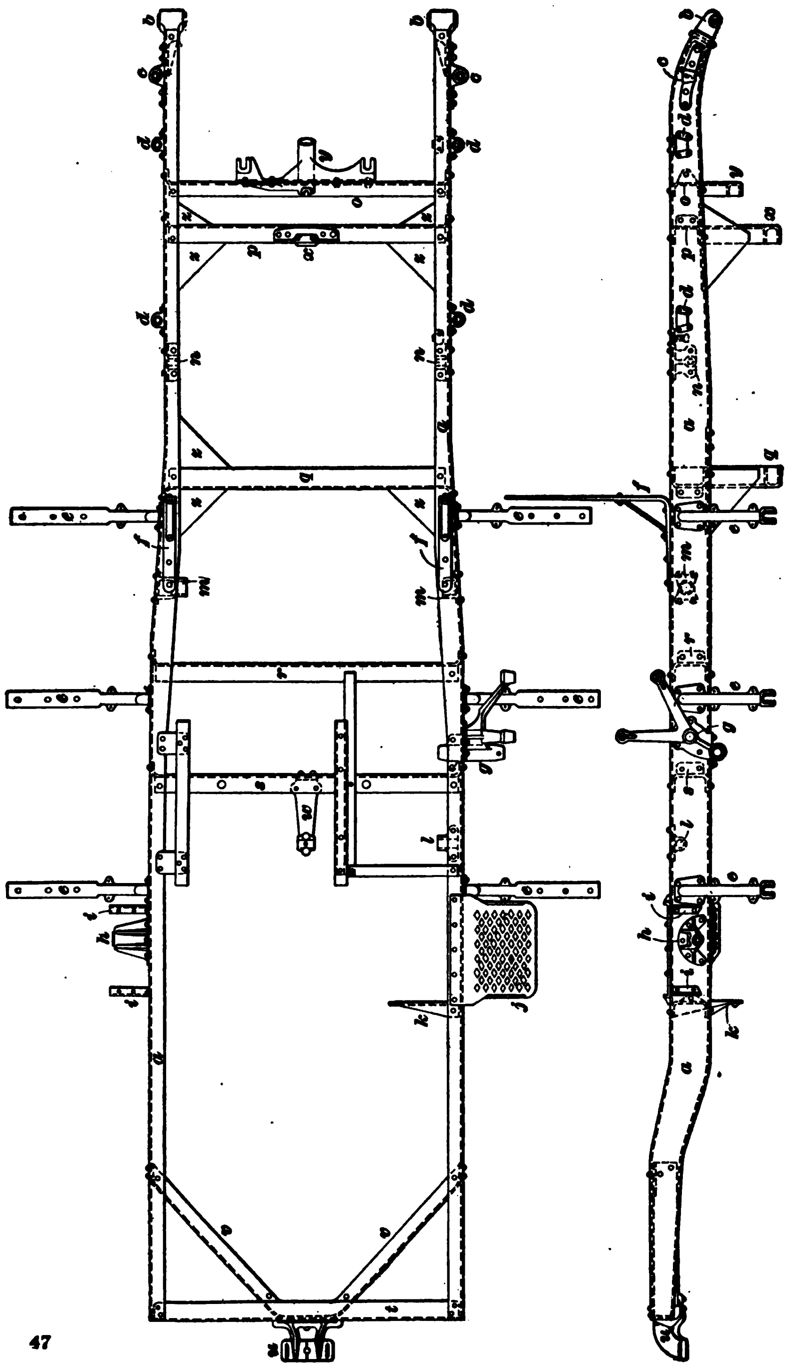


FIG. 38

of moderately large iron or steel angles or of small angle irons used as stiffeners with the comparatively thin steel plates to which they are riveted; and the *pressed-steel frame*, which is made up of parts pressed to shape in huge hydraulic presses.

55. Pressed-Steel Frames.—The **pressed-steel type of frame** is more largely used than any other, being particularly well adapted to meet the requirements of automobile construction, dependence for flexibility being placed on the spring equipment and the method of mounting the machinery.

A typical pressed-steel touring-car frame with various parts riveted to it is shown in Fig. 38. To the side members, or *side bars*, *a*, as shown by the side elevation as well as the top or plan view, are riveted at *b* the *spring horn*, or front *outrigger*, for the front springs; at *c* the supports for the front headlight brackets; at *d*, those for the front *fender irons;* at *e*, the *step hangers* for supporting the *running board;* at *f*, the reinforced braces for the *dash;* at *g*, the *quadrant bracket* for the control levers; at *h*, the bracket for the forward end of the rear spring; at *i*, the supports for the tonneau step *j*; at *k*, the rear hanger for the *muffler*; at *l*, a bracket bearing; at *m*, bracket bearings for the foot-lever shaft; and at *n*, bracket bearings for shackles at the rear ends of the front springs.

To the side members of the frame are also riveted the ends of the *cross-member o* for the radiator, *p* for the front-engine support, *q* for the rear-engine support, *r* for the front-transmission support, *s* for the rear-transmission support, and *t* for rear end of frame. To the cross-member *t* is riveted the bracket *u* for the rear cross-spring, the rear cross-member being stiffened by diagonal braces *v* through which pass the rivets for the cross-spring bracket *u*. To the cross-member *s* is riveted a bracket bearing *w* for the brake rocker-shaft, one end of which has a bearing in the bracket *l*. To the cross-member *p* is riveted a bracket *x* for the front-engine support, while to *o* is attached the bracket support *y* for the radiator and starting crank. *Gusset plates z* are used to stiffen the frame at the forward cross-members. Just beneath the rear

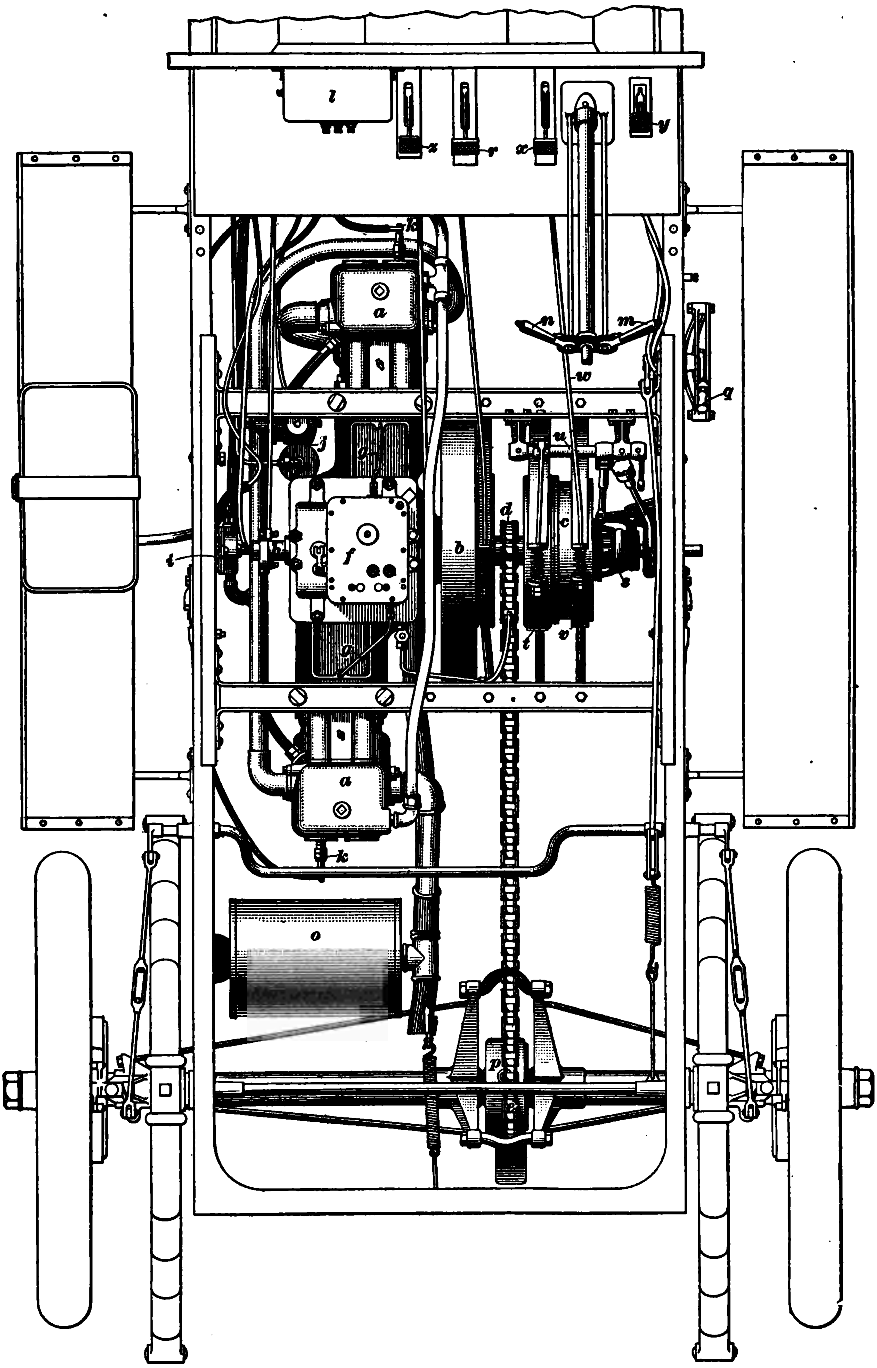


Fig. 39

spring supports *h* is riveted a guide for the *brake equalizing bar*, the ends of which slide in the guide in which is fastened a spring to keep the bar against the under side of the frame and thus prevent rattling.

56. Mounting of Frames.—As a rule, the frame of an automobile is mounted on top of the springs and above the axles. One American firm, however, in order to obtain a low center of gravity while using an extra-large size of wheel, makes use of what may be termed an *underslung frame*, the frame being placed below the axles and suspended from the springs. This construction necessitates the use of a housing through the center of the car and above the driving shaft from the engine to the rear axle in order to provide for the play of the propeller shaft, which otherwise would strike the floor of the car when traveling over rough roads.

POWER PLANT

LOCATION AND ARRANGEMENT

57. The Engine.—The **engine** of single, or center, chain-driven automobiles is generally of the single-cylinder or double-opposed horizontal type and is located under the front seat. Fig. 39 shows a top, or plan, view that illustrates the location of such an engine with the horizontal cylinders *a* lying in a fore-and-aft plane. In this position, the crankshaft, on an extension of which the flywheel *b* and transmission *c* are located, extends crosswise, or athwartship, of the frame. The forward, or transmission, sprocket *d* is thus brought in line with the rear, or differential, sprocket *e*, through which the axle shaft and wheels are driven. As shown, the engine is suspended by bolts from two cross-members of the frame, which is of armored-wood construction. Looking from the rear toward the front of the chassis, the engine is located on the left-hand side, the flywheel occupying a very nearly central position and the driving-

chain sprockets being slightly off center to the right. Placing the engine under the seat tends to throw most of the weight to the rear, where it is needed to enhance the tractive power of the driving road wheels. Generally speaking, the lubricator for such an engine is located on top of the crank-case, as at *f*, pipes *g* conducting the oil to the points at which the pistons are lubricated. The timer *h* and the rotary water-circulating pump *i* are usually located as shown, the carbureter, as *j*, being placed in the most available position for accessibility.

58. For the purpose of making clear all that is shown in Fig. 39, without particular relation to the position or arrangement of the power plant, it may be well to state that *k*, *k* are spark plugs screwed into the ends of the cylinders; *l*, the spark coil attached to the dash; *m*, the spark lever, which is located just below the steering wheel (not shown) and is operated by hand to vary the instant of ignition; *n*, the throttle lever for controlling the supply of fuel to the engine; *o*, the muffler; *p*, the differential gear-case on the rear axle; *q*, the hand-brake lever for the hub brakes on the rear wheel; *r*, a pedal for a brake on the shaft that carries the chain, transmission *c*, and front sprocket wheel *d*; *s*, a sliding, round-nosed piece, ordinarily called a *cone*, which, when forced toward the transmission *c*, brings the high-speed mechanism into operation so that the car travels at its fastest speed; and *t*, a split band around one portion of the circumferentially split transmission gear-case.

When the band *t* is drawn tight, or contracted on its drum, it stops the rotation of the drum and puts the slow-speed gears into operation to drive the car at slow speed. Both the cone *s* and the band *t* are operated from the shaft *u*, to which is attached a hand lever (not shown) at the side of the driver's seat. When this lever is put forwards, the car travels at high speed; when it is thrown back, the car travels at slow speed. The intermediate position of the lever leaves the engine free to rotate without driving the car. Surrounding the other part of the circumferentially split drum is a band *v* that, when gripped on the drum by action of the rod *w* and

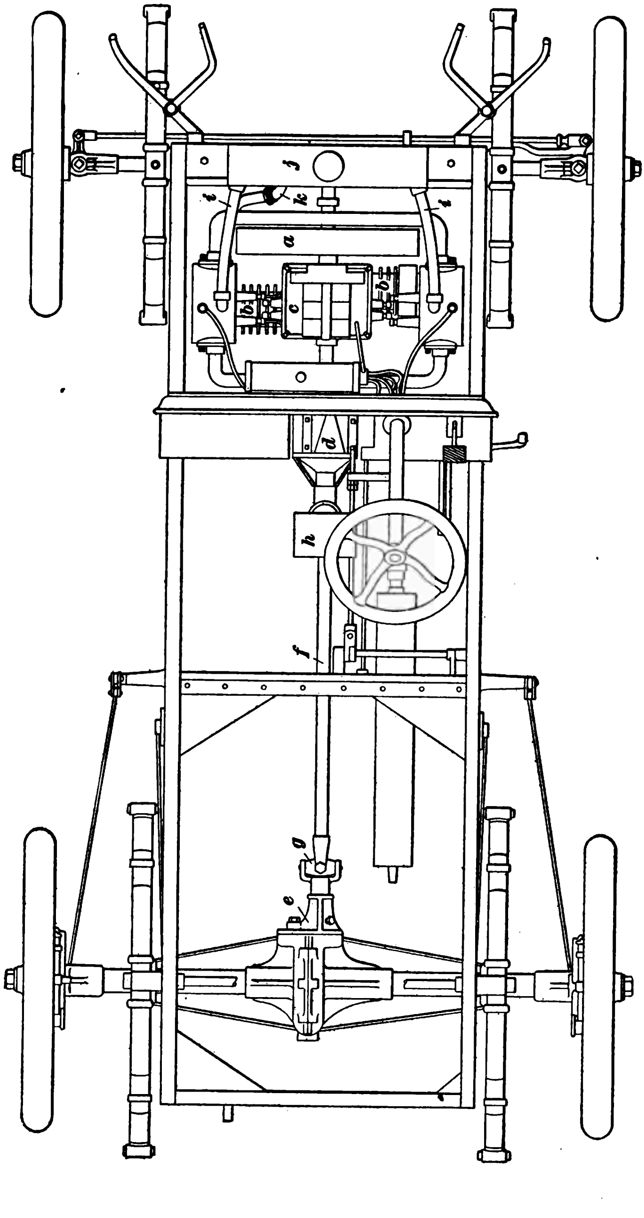


FIG. 40

pedal x, brings into action the reverse mechanism of the change-speed gears, and the car travels backwards while the engine still rotates in the same direction as for forward travel of the car. Gasoline automobile engines never reverse their direction of rotation. The pedal y is connected to a rod that actuates a cut-out on the exhaust pipe, pressure on the pedal serving to open a by-pass and allow the exhaust gases to escape directly into the atmosphere without passing through the muffler. When pushed forwards a compression relief pedal z operates valves or petcocks so as to open up small passages into the engine cylinders. When these valves, called *compression relief valves*, are open, the engine can be started more easily by hand cranking than if the valves are not open. On the left-hand running board is a tool chest, while the electric battery for ignition and the radiator and water tank that form part of the cooling system are all placed under the hood at the front of the car.

59. When the horizontal double-opposed type of engine is used in shaft-driven cars, it is located under the hood at the front end of the car, as shown in Fig. 40. The cylinders occupy a crosswise, or athwartship, position in order that the crank-shaft may lie in a fore-and-aft, or lengthwise, plane, parallel to the side members of the frame. The engine is set in the same position that it would have to occupy in a power boat or launch in order to drive the propeller shaft. The flywheel a is necessarily placed at the forward end of the crank-shaft in front of the cylinders b, which it often helps to cool, the flywheel having arms like the blades of a fan blower. To the rear of the engine crank-case c is located the clutch and transmission, or change-speed, mechanism in the gear-case d. The connection between the transmission shaft projecting from the rear end of the gear-case d and the driving pinion shaft projecting from the forward side of the differential housing e is made by the propeller shaft f. At the ends of this shaft are two universal joints g and h that permit of lengthwise motion without throwing any undue stress on any of the driving or other elements of the machinery.

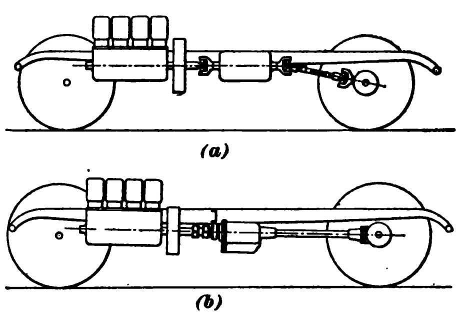
FIG. 41

Instead of using a rotary, or centrifugal, pump, as in Fig. 39, to force a circulation of the cooling water, the engine cylinders are, in this case, cooled by a *thermo-siphon* system of water circulation. This system resembles in a way that used to heat a building with water that is heated in a boiler and then passed through radiators in which it is cooled. The pipes *i* make water connection between the cylinders of the engine and the radiator *j*. Another pipe *k* connects the bottom of the radiator to the lower side of the cylinders.

60. Vertical engines of the multicylinder type are commonly located as shown in Figs. 3, 4, 5, and 6, whether the shaft or the double side-chain drive is employed. The engine is placed under the hood with the carbureter, mechanical oiler, magneto, and other power-plant auxiliaries.

TRANSMISSION

61. The mechanism by which the power developed by the engine is transmitted to the rear driving wheels is made up of a number of elements whose relative positions, as actually found in the chassis, are clearly shown in Fig. 41. When the leather-faced cone clutch *a* is thrown in by means of the foot-lever *b*, power is transmitted through the coupling *c* to the change-speed, or transmission, gears in the gear-box *d*, and thence through the universal joint, or coupling, *e* to the propeller shaft *f*. This shaft is surrounded by the torsion tube *g* attached by capscrews to the housing *h* that encloses the bevel driving pinion. The latter meshes with the differential driving gear within the housing *i*, and this gear drives the axle shaft, one wheel spindle of which projects from the axle housing at *j*.


(a)
(b)
FIG. 42

62. On referring to Figs. 4, 27, 28, and 41 it will be noticed that the propeller shaft does not lie in the same horizontal plane as the engine and transmission shafts, but occupies the position shown somewhat exaggerated in Fig. 42 (*a*). The crank-shaft and the driving shaft of the transmission are in line, but the propeller shaft is set at an angle to the transmission and rear axle, necessitating the use of two universal joints, one at each end of the shaft. When the angle is small, as in Fig. 4, it is customary to eliminate the universal joint at the axle end of the propeller shaft. With what is commonly called a *straight-line drive*, the universal joint is commonly located between the engine clutch and transmission, the crankshaft, transmission shaft, and propeller shaft all being arranged in the same straight line, as shown in Fig. 42 (*b*).

UNIT POWER PLANT

63. On referring to Figs. 3, 4, 5, 6, 39, 40, 41, and 42, it will be observed that the engine and transmission are separate units, between which, as a rule, some form of universal joint is used to give flexibility and thus relieve the parts of the stresses that otherwise would be thrown upon them in passing over rough, uneven roads. The same object is accomplished with what is known as the unit power plant and the *three-point suspension.*

64. As shown in Fig. 43, the **unit power plant** type of construction consists in mounting the engine cylinders, clutch, and transmission in a single rigid casing that is usually supported at two points at the forward end and at one pivotal point at the rear, or transmission, end. This method of supporting the unit type of power plant is known as the **three-point suspension.** In some cases, the flywheel is also enclosed. One object of the unit type of construction is to keep oil in and dust out; another is to have every part in absolute and undisturbed alinement under all conditions; still another object is to permit the power plant to be assembled as a whole and put into position without fitting it into place.

65. In applying the unit principle to the power plant shown in Fig. 43, the cylinders *a* of a double-opposed engine are bolted to the crank-case end of the casing *b*. This casing carries the two adjustable main bearings *c* for the engine crank-shaft, on the forward end of which the flywheel *d* is located. To the rear of the crank-case and close to it is the multiple-disk clutch *e*, and back of this clutch are the sliding-gears *f*, at the transmission end of the casing *b*, the cover to

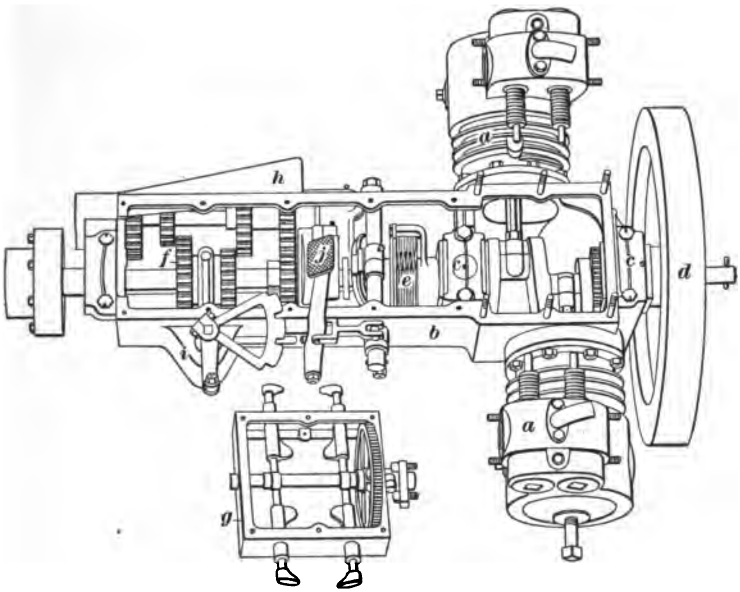


FIG. 43

which has been removed. The valve-actuating mechanism is mounted in the frame *g* that fits over the crank-case and on top of which a cover is placed. The projection at *h* is provided to house the gears on the transmission lay shaft, while that at *i* encloses the gear-shifting mechanism, which is so arranged that the gears cannot be shifted until the disk clutch *e* has been thrown out of engagement by the foot-pedal *j*.

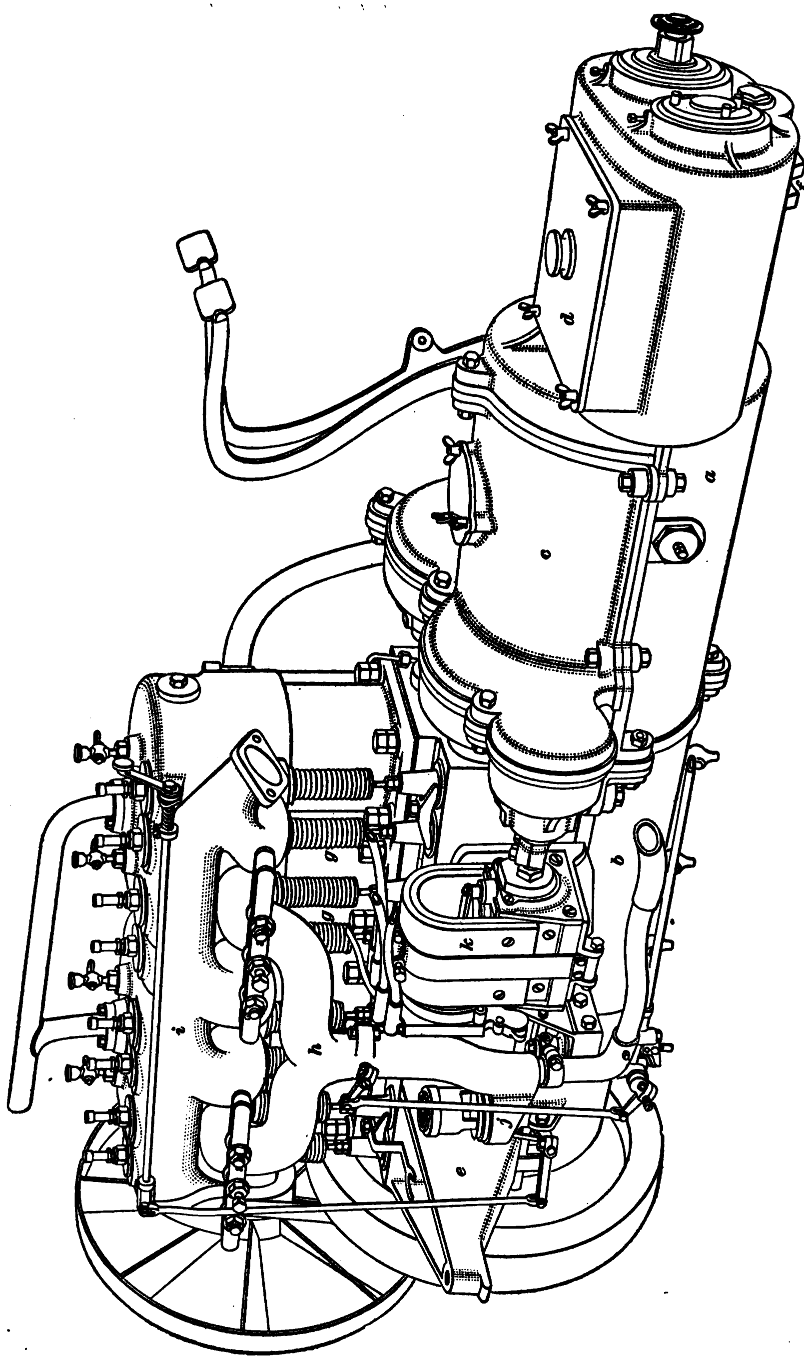


FIG. 44

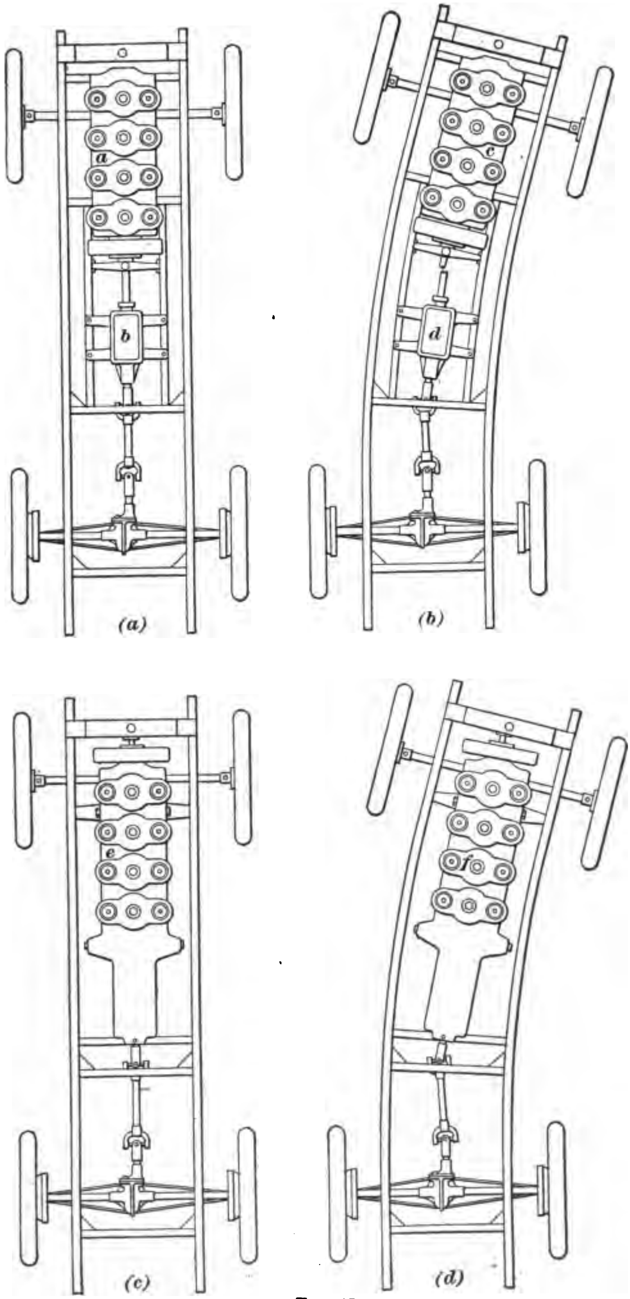


FIG. 45

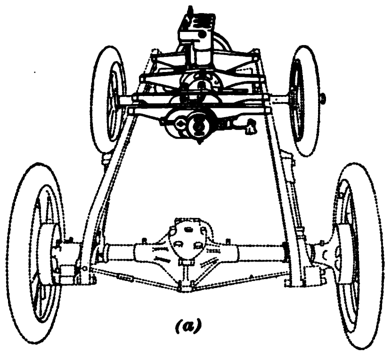
66. The arrangement and external appearance of another unit power plant with the more common multicylinder vertical type of engine is shown in Fig. 44. In this instance, a two-part casing is used, the part *a* that encloses the clutch and the transmission being bolted to the engine crank-case *b*, as shown. Access to the clutch and to the gears by means of which the magneto shaft, cam-shaft, and pump shaft are driven is had by removing the cover *c*, and the change-speed gears are reached by removing the cover-plate *d*. At the forward end, the power plant is supported by two arms, as *e*, that rest on and are bolted to the side members of the frame. The rearward end is pivotally supported in a rocker, or cradle, joint at *f*, on a dropped cross-member of the frame. The illustration shows the side of the power plant on which are located the valves *g*, the inlet manifold *h*, the exhaust header *i*, the carbureter *j*, and the magneto *k*.

67. The advantages of the three-point suspension for the power plant of an automobile will become apparent on studying Figs. 45 and 46.

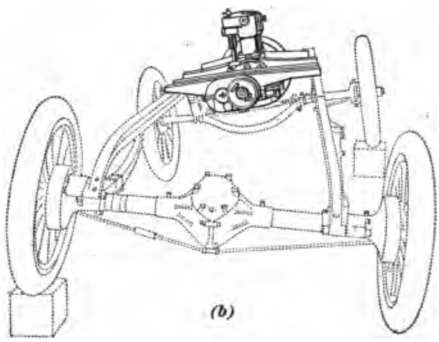
In Fig. 45 (*a*) is shown conventionally the chassis of an automobile in which the engine *a* and transmission *b* are separate units that are in line with each other and parallel to the side members of the frame when the car is traveling straight ahead over a perfectly level surface. In Fig. 45 (*b*) is shown the effect, much exaggerated, of stresses tending to throw the engine and transmission out of alinement, the shaft between the engine *c* and the transmission *d* being broken.

Fig. 45 (*c*) shows, under the same conditions as in Fig. 45 (*a*) a unit power plant *e* supported at three points. The greatly magnified distortion of the frame, as shown in Fig. 45 (*d*), has practically no effect on the power plant *f* because of its flexible, single-point attachment at the rearward end to one of the cross-members of the frame.

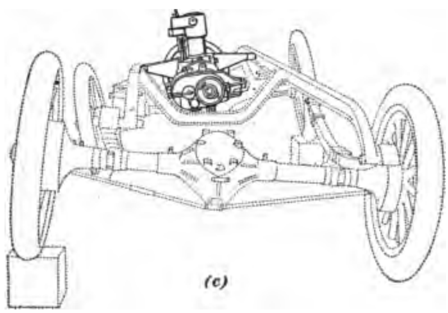
68. Some idea of the stresses to which the engine and transmission are subjected when they are installed as separate units and bolted rigidly to the frame or subframe at four or more points can be gained from a study of Fig. 46.



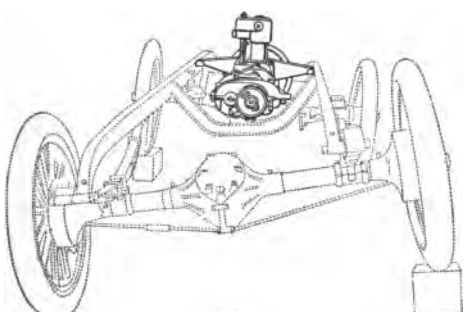
(a)



(b)



(c)



(d)

FIG. 46

In view (*a*) is shown an engine and transmission separately mounted and fitted for demonstration purposes with a number of false feet, or supporting arms, that rest on the side members of the frame. In this view, these arms lie in the same horizontal plane, but when one of the rear wheels and the front wheel diagonally opposite are raised, as shown in (*b*) the great twisting stress thereby thrown on the frame distorts it, and the arms on the left if not bolted down would be lifted away from the frame. When the power plant is suspended at three points, as shown in (*c*) and (*d*), distortion of the frame does not throw any great stress on the power plant, which at the rear end is free to move and thus compensate for inequalities in the road without affecting the alinement of the parts.

BODIES AND ACCESSORIES

TYPES OF BODIES

GENERAL CLASSIFICATION

69. The **body** is that part of an automobile which provides accommodations for the carriage of passengers. It is the superstructure that rests on the frame of the chassis, to which it is fastened in such a way that it may readily be removed to facilitate repairs or to make possible the substitution of one style of body for another.

70. Bodies may be classified under two heads, namely, *open bodies* and *closed bodies*. The former are used for running around town and for touring in summer, while the latter are popular for winter use. The folding tops with which the open bodies are usually equipped afford protection from sun and rain to both the driver and passengers. Closed bodies are fitted with side curtains, by means of which the space between the driver's seat and the wind shield at the dash is entirely closed, thus protecting the driver in extremely cold winter

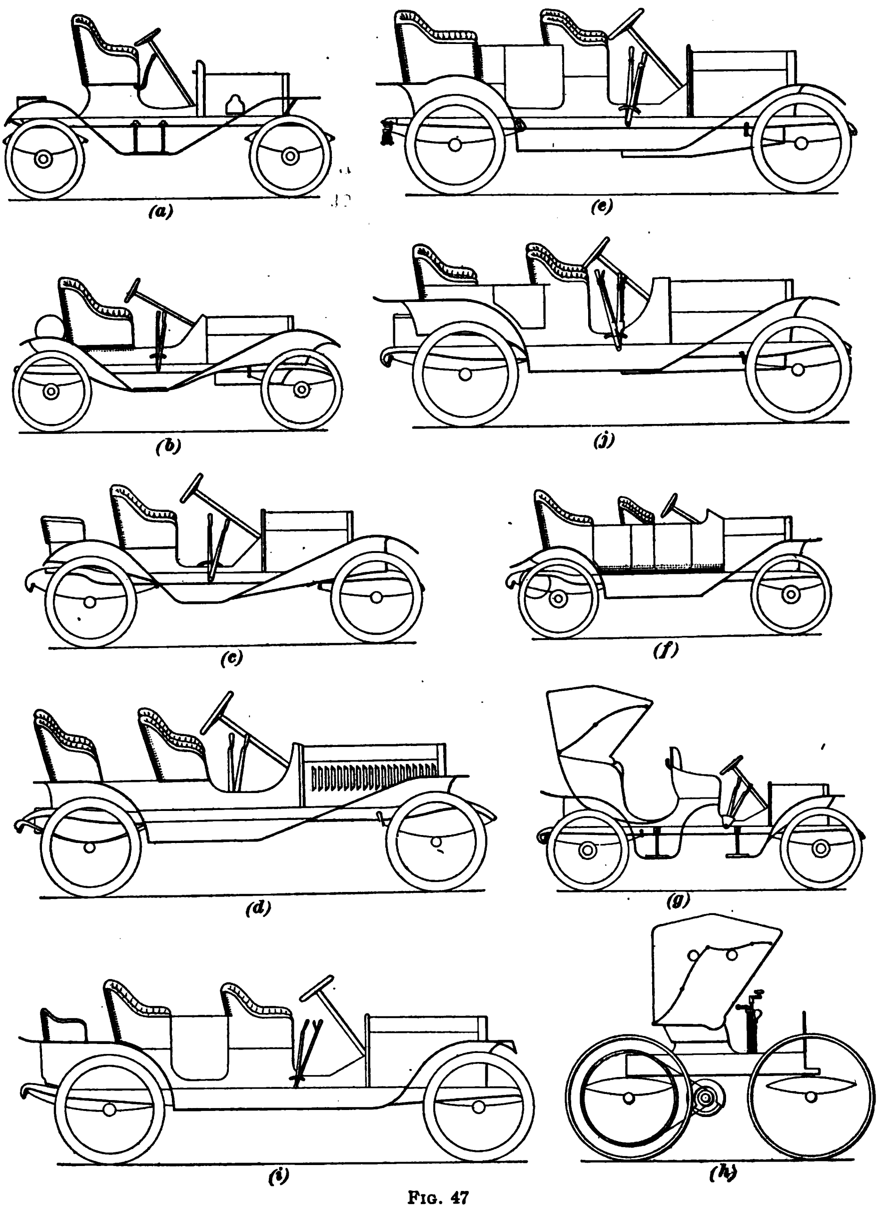


FIG. 47

weather. The side curtains are provided with large celluloid windows through which can be seen clearly the mirror that gives the operator a good view of the road at the rear of his car. Closed bodies are frequently provided with means for heating them, and those used for touring purposes are commonly provided with luxurious toilet accessories hung on hinges so as to permit them to be folded up out of sight when not in use.

SEATS AND DASH

71. Seats.—Some of the small *two-passenger*, or *runabout*, open bodies have **divided, or bucket, seats** like those shown in Fig. 47 (*d*), while others have undivided seats similar to the seat shown in Fig. 47 (*a*). For carrying an extra passenger, single bucket seats, usually called **rumble seats,** are much used on runabouts. Double-bucket seats were designed to support the driver comfortably on all sides and prevent hampering of his movements through crowding.

The *rear*, or *tonneau, seat* of most touring cars is made much wider than the front seat, so as to accommodate three passengers, and is placed at a higher level so that its occupants may have a view unobstructed by the two persons on the front seat.

72. Dash.—Some automobiles are fitted with a *straight dash* of wood, as shown in Fig. 47 (*e*) and (*i*), and others, as shown in Fig. 47 (*a*), (*b*), and (*d*), have a *curved dash* of pressed steel. The curved type of metal dash is popular because of the protection it affords to the spark coil, the lubricating apparatus and other devices mounted thereon.

RUNABOUTS

73. In a general way, it may be assumed that the term **runabout** should apply only to light cars having a single seat for two passengers, without a rear seat, but with or without a tool box at the back, as shown in Fig. 47 (*a*). However, cars having round or oval gasoline tanks behind the front seats, as shown in Fig. 47 (*b*), are also classified as runabouts.

Some manufacturers apply the term runabout to cars having a single rumble seat behind the front seat, as shown in Fig. 47 (*c*), while others classify such cars as *roadsters*. It seems to be the prevalent practice, however, to confine the use of the term roadster to cars having a double rumble, or two-passenger seat behind the front seat, as in the car shown in Fig. 47 (*d*), no side doors being used. The term *surrey* is also applied to such bodies.

As the terms are used at present, there are no clearly defined characteristics by which the runabout may be distinguished from the roadster type of body.

74. The terms *gentlemen's roadster*, *semiracer*, and *racer* are applied to cars that may be said to be in the runabout class, to which the *doctor's stanhope* also belongs.

The term **racer** is applied to automobiles stripped of fenders, running boards, and all body work except that actually required to support the two individual seats with which such cars are fitted—one for the driver and the other for his mechanician. An unusually large gasoline tank is carried just back of the seats.

Semiracers are two-passenger cars made to resemble the racers, but fitted with fenders, running boards, mud-aprons, and more or less body work of pleasing proportions and high finish.

The **stanhope** has a single seat for two passengers, with a large carrying space under a hinged deck behind the seat. It is equipped with what is known as a *stanhope top*, like that used on horse-drawn vehicles, and is especially adapted for the use of physicians, for whom it was designed.

TOURING CARS

75. Common Type.—The regulation type of **touring body,** as shown in Fig. 47 (*e*), differs from the runabout body in that it has a *tonneau* (pronounced *ton-no*) or rear seat section that flares outward at the back, bulging out over the rear wheels, as shown in Fig. 2, so as to provide comfortable seat-

ing capacity for three persons. The tonneau is entered from the side.

As originally used by the French, however, the term tonneau, meaning *tub*, was applied to a body having a door at the back to give entrance to a rear-seat section of tub-like form. Cars equipped with so-called *rear-entrance bodies* are still occasionally seen on the streets, but for a number of years all the touring-car bodies manufactured have been of the *side-entrance type*.

The rear-entrance tonneau was abandoned because passengers in alighting from the car were obliged to step out into the road instead of on the sidewalk. Besides, the lines of the old time rear-entrance bodies were far less pleasing than those of the present-day side-entrance type, and the bodies were less comfortable to ride in.

76. Special Types.—Some manufacturers have applied the term *tonneauette* to a type of touring body of limited carrying capacity, the rear seat providing room for only two passengers. Other makers use such expressions as *miniature tonneau*, *pony tonneau*, *baby tonneau*, and *toy tonneau*, the last two being the most popular designations. Except for the difference in carrying capacity and smaller leg room, this type of body, as shown in Fig. 47 (*j*) is similar to the regular touring-car type.

The type of body used on the *victoria*, or *cabriolet*, is shown in Fig. 47 (*g*). The body used with the buggy type of runabout is shown in Fig. 47 (*h*).

77. What is commonly known as a **close-coupled touring car,** Fig. 47 (*i*), is one having a body of the toy, or two-passenger tonneau, variety, the rear seat being located so that the passengers are either in front of or just over the center line of the rear axle. In touring cars of the regular type, the rear-seat passengers are back of the center line of the rear axle.

78. Some touring cars are fitted with *detachable tonneaus*, by the removal of which they are converted into runabouts.

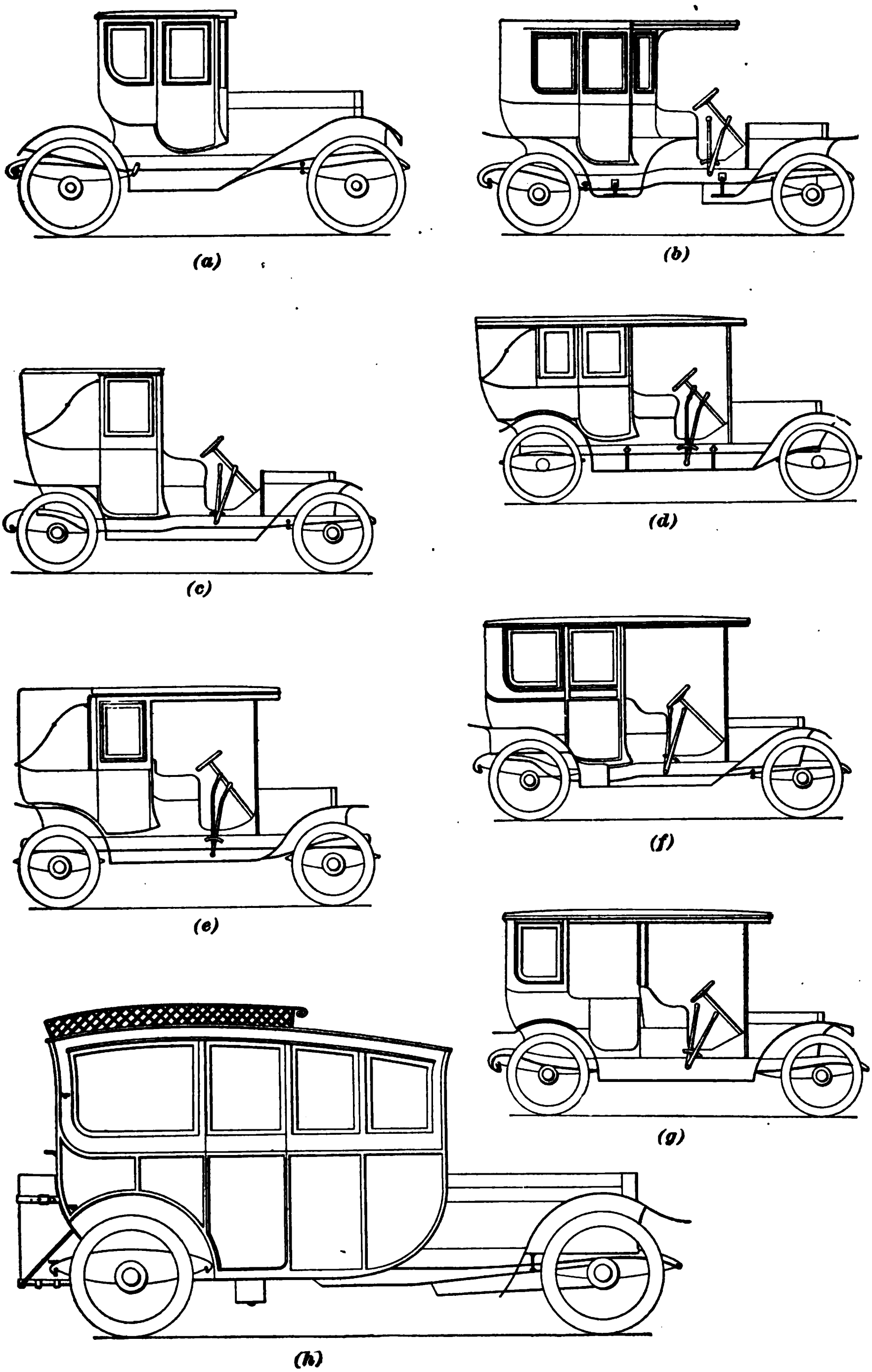


Fig. 48

The latter are sometimes fitted with *folding tonneaus*, by means of which they can be transformed into cars resembling the double-rumble type, of roadster or tourabout. Cars thus equipped are said to have *convertible bodies*.

79. Torpedo Type.—In Fig. 47 (*f*) is shown the **torpedo,** or **gunboat,** type of body, so named because of the resemblance of its rear end to the stern of a modern torpedo boat. This type of body was originally designed to afford protection from dust, but it has been found to give equally desirable protection against cold in winter touring. Frequently, the space between the dash and front seats is permanently closed on the change-speed, or control-lever, side of the car, a side-entrance door being provided in the side opposite the control levers. In some cases two side-entrance doors are used at the front seat, the control levers being located just inside the door at one side. Some cars of the torpedo type have no running board, two separate steps, one for the front and the other for the rear, being used instead.

CLOSED AND SEMICLOSED BODIES

80. Coupé.—As shown in Fig. 48 (*a*), the **coupé** is a type of closed body usually designed for carrying two persons. It is especially adapted for the use of physicians in cold and stormy weather.

81. Landaulet.—For use in the suburbs or in the city, a type of closed body known as the **landaulet** is very popular. As shown in Fig. 48 (*d*), an extension of the top covers the driver's seat, and a wind shield in front affords further protection to the driver in cold and rainy weather. In warm, pleasant weather the glass panels back of the driver, at the sides, and in the doors may be let down into spaces provided to receive them, and the rear portion of the body, being made of flexible leather, may be folded down and back, transforming the previously closed body into one having some of the characteristics of those of the open type. When, as is sometimes the case, provision is made for removing the *canopy top*

over the driver's seat, the framework back of it, and the upper part of the frames of the side doors, the body is converted into one more nearly like those of the fully open, or touring type.

Landaulets are usually provided with folding seats for two passengers, who must ride backwards, the fixed rear seat accommodating two or three passengers facing forwards. In the horse-drawn vehicle from which the landaulet-automobile body takes its name, there are two seats facing each other and the top is made in two sections so as to permit of folding them back and thus make an open carriage.

82. Town Car.—It will be noticed that the landaulet body differs from what is known as the **town car,** Fig. 48 (*e*), principally in the omission of the glass panel at the rear of the side doors. In all other respects the so-called town car very closely resembles the landaulet, of which it may be said to be a modified type.

83. Limousine.—For private use, the **limousine body** is the most popular of bodies of the closed type. It affords a maximum of comfort, combined with an elegant luxuriousness not common to other types of closed bodies. As shown in Fig. 48 (*f*), the upper part of the doors and body is made up of glass set in sash that may be lowered into recesses provided to receive them. Thus, when the weather is warm the passengers need not suffer from heat or lack of fresh air. The glass partition back of the driver's seat is sometimes arranged so as to swing upwards against the roof, from which it is suspended. The driver's seat is sometimes enclosed by body work, like that of the limousine proper, one manufacturer styling such a body a *fore-door limousine*.

84. Brougham.—As shown in Fig. 48 (*b*), the **brougham** is a type of closed body that somewhat resembles a limousine. It is distinguished from the latter, however, in having a short canopy top over the driver's seat; also, the wind shield is omitted, and the fenders are arranged like those of the victoria, or cabriolet, Fig. 47 (*g*). The brougham is designed to carry either two or four passengers.

85. Demi-Limousine.—A few manufacturers supply cars with what is known as a **demi-limousine body,** as shown in Fig. 48 (*g*). Protection from sun and rain is afforded by a canopy top supported by stanchions at the dash, where a wind shield is mounted, and at the back of the front seats. Above the back of the rear seat and enclosing it is a wooden framework containing heavy plate-glass windows at the side and back, as in the regular limousine body. This framework, together with the canopy top and wind shield attached thereto, is made removable, so that the body may be converted into one of the fully open type. The space between the wind shield and the side windows of the tonneau-enclosing body work is not closed except when showers necessitate the use of the side curtains, which, when not in use, are rolled up under and fastened to the canopy top.

86. Taxicab.—To adapt it for use in summer as well as in winter, in fair as well as in foul weather, the **taxicab** body, as shown in Fig. 48 (*c*), is made with a top that may be folded down and back, as in the landaulet. Taxicabs have no canopy top nor wind shield, although cars thus equipped and fitted with taximeters are used for hacking purposes, and are commonly called taxicabs by the traveling public. Some taxicabs are, however, fitted with a small leather hood like a miniature victoria top over the driver's seat. The glass windows in the side doors may be lowered into recesses provided for them, as may also the windows at the back of the driver's seat.

87. Touring Coach.—Special types of bodies for hunting, touring, and other purposes are commonly made to order, and fitted to standard and special chassis. One notable example is shown in Fig. 48 (*h*), which illustrates a **touring coach** especially designed to accommodate comfortably several persons besides the driver. Large baggage-carrying capacity is provided at the rear and on top of the coach, within which are provided toilet accessories and every convenience for touring. The vehicle shown will seat nine persons, and contains cooking, dining, and sleeping accommodations

for five. Screens are provided for the windows, the lavatory is supplied with hot and cold water, an ice box is carried, and storage for provisions is provided.

When suitably equipped, the fore-door limousine mentioned in Art. **83,** can be used as a touring coach. In some vehicles the seat alongside of the driver is reversed so that the occupant thereof faces the occupants of the rear seat.

88. Body Construction.—The construction of an automobile body of the open five-passenger touring-car type

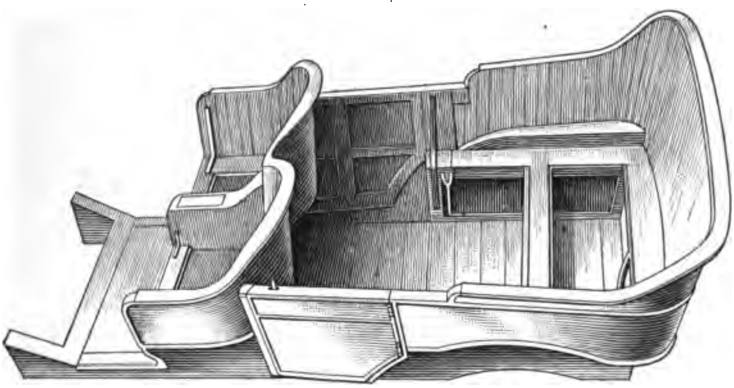


Fig. 49

is shown in Fig. 49. The body is of wood bent to the required shape. Some bodies are made up of sheet metal fastened to a heavy wooden framework, and others are made up of metal castings, usually aluminum. The sills on which the superstructure of the body is built and on which the floor boards rest are made of heavy stock and are well tied together, angle plates of metal being used wherever necessary to insure stiffness.

ACCESSORY FITTINGS

AUTOMOBILE TOPS

89. Canopy and Cape Tops.—Except on closed and semiclosed bodies [see Fig. 48*g*], the **canopy top** is not now used, open bodies being fitted with **cape tops,** Fig. 50, that may be folded back out of the way at will.

The once popular canopy top, being of rigid, non-folding construction and securely fastened to the body by means of heavy metal stanchions or standards, was not readily detachable and had to be entirely removed when its protection was

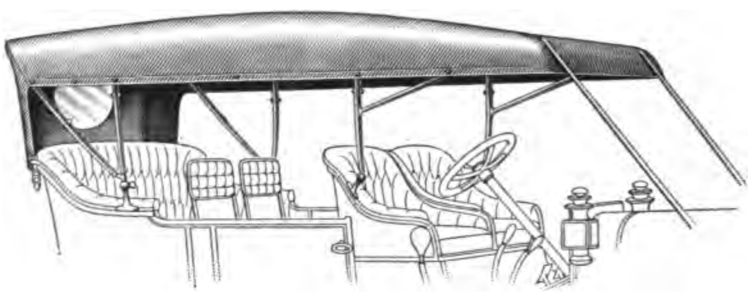


Fig. 50

not desired. For this reason, its use on open cars was discontinued. Protection against wind and rain was afforded by side curtains. These were buttoned to the body when in use and rolled up under the canopy out of the way when not required.

The side curtains used with cape tops are not rolled up under the top, but are usually folded and carried under the rear-seat cushion or in leather pockets especially provided for them.

90. Victoria Top.—In Fig. 47 (*g*) is shown a **victoria top.** This type of top is not much used except on electric pleasure vehicles, cabriolets, or victorias, and on the so-called stanhope type of runabout designed for doctors' use.

Open cars of the baby-, or pony-tonneau touring type, however, are sometimes fitted with victoria tops, but they are used over the rear seats only.

DASH EQUIPMENT

91. Horn.—Generally speaking, the **horn** forms part of the equipment attached to the dash of an automobile. As

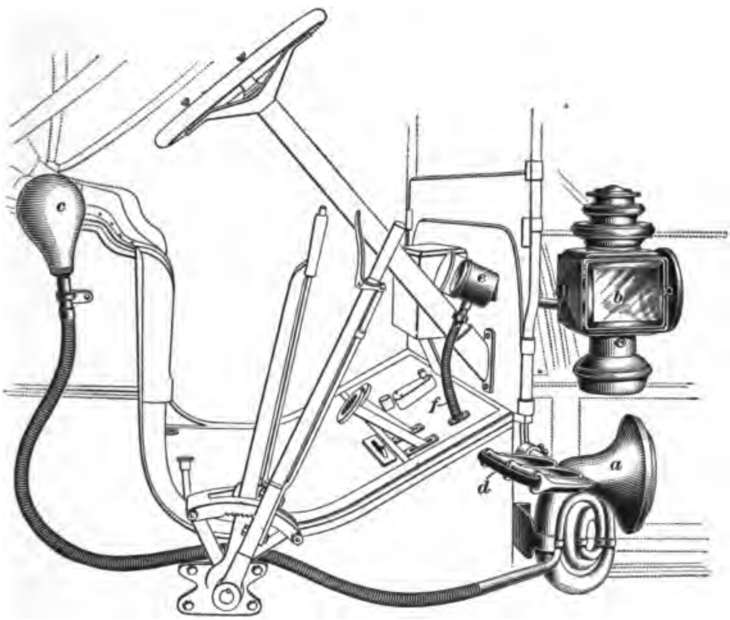


FIG. 51

shown in Fig. 51, the horn *a* is frequently located just below the oil side lamp *b*. The rubber bulb *c* for blowing the horn is sometimes fixed to the side of the driver's seat, as shown, and sometimes it is fastened to the footboard so that the horn may be blown by pressing the bulb with the foot. It is also occasionally mounted on the steering column or on the steering wheel.

92. Tire Holders.—Spare tires are commonly carried in **metal tire holders,** one of which, as *d*, Fig. 51, is

attached to the dash, while the other is mounted on the running board on the control-lever side of the car. The tire or tires, as the case may be, are held in place by leather straps or by metal clamps that can be locked with a key or held in place by padlocks.

93. Speedometer.—To determine the distance and speed of travel, most automobiles are fitted with a **speedometer.** This device registers the total distance covered during the season, the distance of each trip, and the rate of

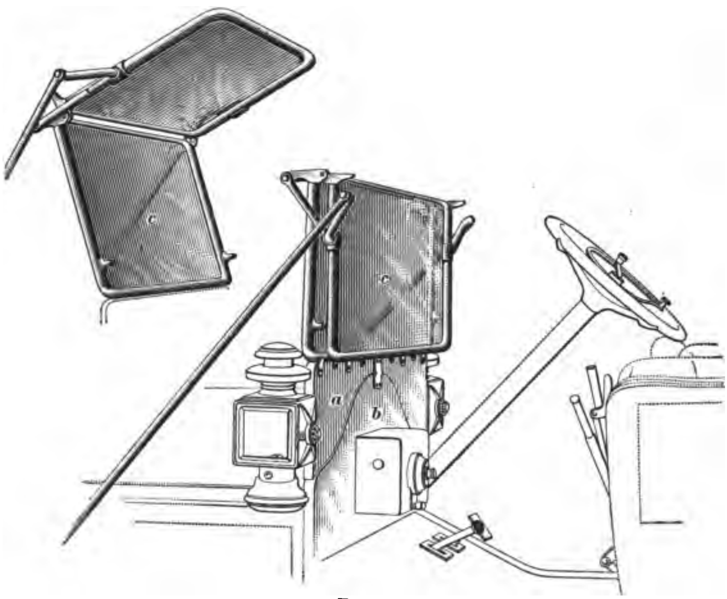


Fig. 52

speed at which the car is moving at any particular instant. The speedometer is usually mounted on the dash, as shown at *e*, Fig. 51, the flexible shaft by which the speedometer mechanism is driven being carried in the flexible tube *f*. The flexible shaft is usually driven by two spur gears and a bevel pinion. One of the spur gears is concentrically mounted on one of the front wheels and meshes with a smaller spur gear on a bevel-pinion shaft at right angles to the large spur gear around the hub of the front wheel.

94. Wind Shield.—As a protection against the wind when driving in cold weather or at high speed on the road, a **wind shield** forms part of the equipment of the modern automobile. It is attached to the dash, as shown in Figs. 51 and 52. The filler board *a*, as shown in Fig. 52, is cut out to suit the shape of the dash *b*, and to this board is applied the wind shield *c*. Present-day wind shields are of the *folding type*. Some have a single fold and others have a double fold, so that they may be made to lie flat in a horizontal plane parallel to the top of the hood.

LAMP EQUIPMENT

95. The lamp equipment of the modern automobile usually consists of two acetylene *headlights* *a*, Fig. 53, two kerosene oil *side lamps* *b*, and a kerosene-oil *tail-lamp* *c*. The headlights are mounted in lamp brackets attached to the

FIG. 53

spring horns in front of the radiator, and the side lamps, as shown at *b*, Fig. 51, are mounted on side brackets attached to the dash. The tail-lamp is mounted on a lamp bracket at the extreme rear of the car so as to throw its light on the

license tag and warn off other vehicles that may approach from the rear, a red bull's eye being provided for that purpose.

96. The construction of a popular type of **acetylene headlight** is illustrated in the cross-sectional view shown in Fig. 54. To such headlights electric-lighting fixtures are sometimes applied, as shown. On the tube that holds the acetylene-gas burner *a* is detachably mounted an electric-light bulb *b* that is supplied with current for electric lighting by a storage battery or by the magneto used for ignition purposes. When acetylene is used, the electric-light bulb is dropped into the position indicated by the dotted lines. To obviate the diffusion of light a silvered mirror *c* is provided. This mirror projects the rays of light from the lamp in parallel lines. Such headlights are fitted with split-glass fronts, so as to obviate breakage due to the heat.

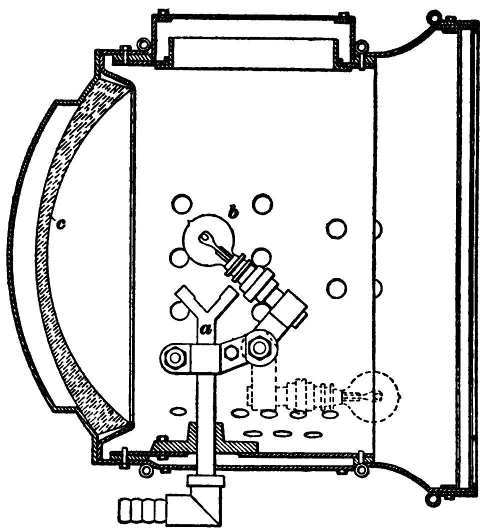


FIG. 54

SHOCK ABSORBERS

97. In order to prevent excessive vibration of the body of the car while passing over rough roads, it is customary to use some form of **shock absorber** to modify the action of the springs. There are three types of such devices: (1) those which depend on the frictional resistance of two or more surfaces in contact; (2) those which depend on the non-compressibility of liquids; and (3) those which depend on the action of some kind of supplementary springs.

98. One of the most widely used types of shock absorber is shown in Fig. 55. It is made up of circular disks. Some of these move with the arm *a*, which is attached to the frame *c* in the manner shown, and some with the arm *b*, which is attached to a special spring clip *d* or to a lug carried on a plate held in place by both spring clips. The frictional tension on the disks may be adjusted by loosening or tightening the nut *e*. This nut presses against a five-fingered bearing plate *f* that carries a pointer *g* for indicating the degree of pressure on the outer disk. The action of the springs is modified by the frictional resistance of the disks when the arms *a* and *b* move toward each other, as when the springs are compressed, or away from each other when the springs recoil.

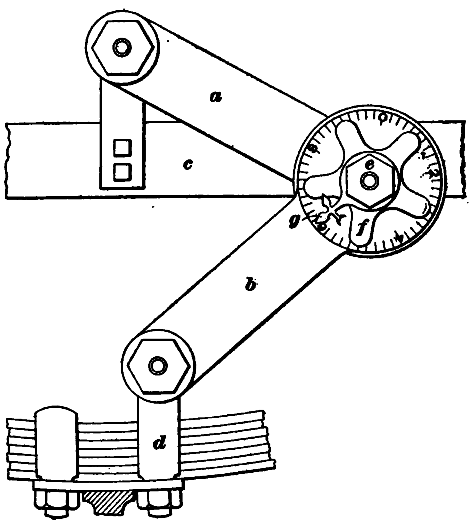


FIG. 55

99. In one type of the so-called **fluid shock absorber,** a piston reciprocates in a cylinder in which there are no valves. A small by-pass is provided in the side of the cylinder, so that the frictional resistance to the passage of air through the by-pass from one side of the piston to the other is such that the passengers practically ride on an air cushion.

In another fluid shock absorber, glycerine is placed in a vertically arranged cylinder that is connected to the axle, a piston that moves inside the cylinder being connected to the frame. Under alternate compression and expansion of the springs, the glycerine is forced through small passages from one side of the piston to the other. The hollow piston rod is

provided with a regulating valve by which the modifying effect of the shock absorber may be varied at will.

100. Several shock absorbers of the **spring type** are illustrated in Fig. 56.

The devices shown in (*a*) and (*b*) have no effect on the compression of the springs, serving merely to limit their movement on the recoil. For this reason, they are called **recoil checks.** They are designed to eliminate upthrow of the body in passing over "thank-you-ma'ams" or other obstructions in the road, and to prevent breakage of the springs by absorbing the recoil.

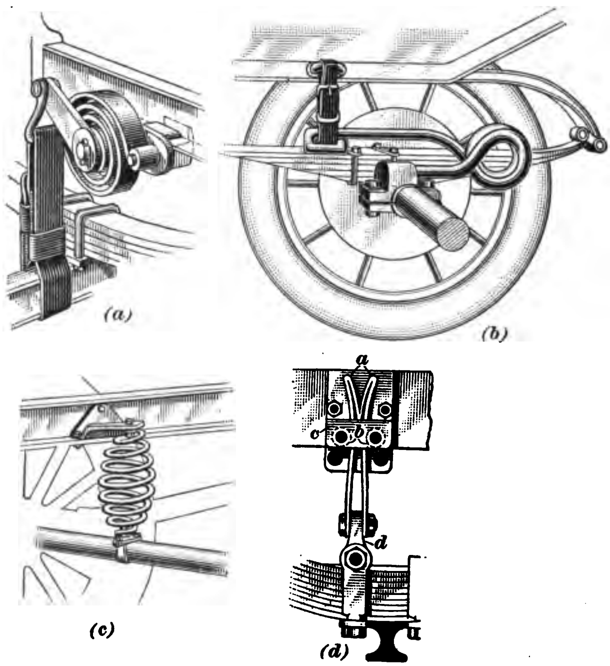


FIG. 56

In (*c*) is shown a simple coiled spring attached to the frame and to the axle, so as to be in compression during the descent of the body and in tension during its rise, and thus modify the spring action in both directions.

The absorber shown in (*d*) consists of two leaf springs *a* whose upper ends are turned backwards, as shown, to keep the springs separated and in contact with the rollers *b* between which they work. The rollers are carried in a bracket *c* bolted to the frame. The lower ends of the spring leaves *a* are attached to the axle by a kind of universal coupling *d*, as shown. The compression of the body springs is not as much affected as the recoil action, which is resisted by the friction due to drawing the leaf springs between the rollers *b*.

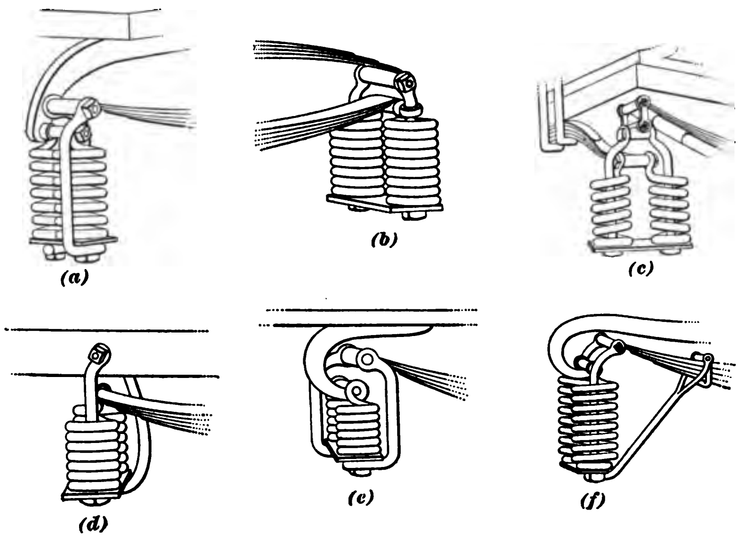


FIG. 57

101. What are known as **supplementary spiral springs,** Fig. 57, are much used as shock absorbers. The method of attachment to an outside hanger carrying a stud on which the end of the spring is hung is shown in (*a*). Attachment to a full-elliptic spring is made as shown in (*b*). In (*c*) is illustrated the application of a supplementary spring to one side of a platform body spring, and in (*d*) is shown the shackles attached directly to a spring above the spring end. In (*e*) is shown a curved hanger with shackles attached to a hanger below the spring end. Attachment to a scroll-end spring is made as shown in (*f*).

GASOLINE AUTOMOBILE ENGINES

(PART 1)

PRINCIPLES OF OPERATION

FOUR-CYCLE PRINCIPLE

DEFINITIONS

1. An **internal-combustion engine,** through the use of some type of which all gasoline automobiles are driven, is one in which a combustible mixture of air and gasoline (or other vaporized liquid fuel) is ignited and burned within the engine cylinder; the heat energy of combustion is transformed into mechanical energy, or *work*, by the action of the products of combustion on the movable piston within the cylinder. The burning of the fuel results in the production of gases of high temperature and pressure, which act directly on a piston that moves back and forth in a cylinder to which the air and fuel are admitted and from which the burned gases are discharged by means of suitable valves. In most automobile engines, work is done on one side of the piston only; such engines are known as *single-acting engines*. In some internal-combustion engines for other purposes, work is done on both sides of the piston, and these are known as *double-acting engines*.

2. Some of the essential parts of a simple form of internal-combustion engine are shown in Fig. 1. The *cylinder a* is

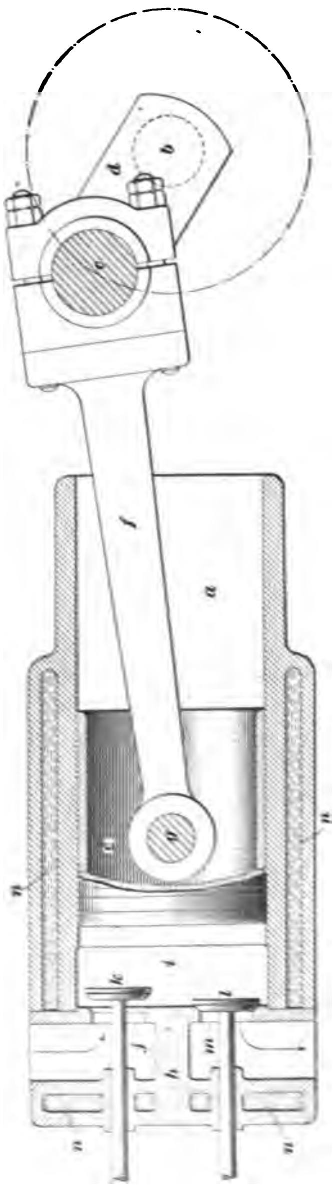


FIG. 1

horizontal. This portion of the cylinder is known as the *barrel*, and the hole, as the *bore*. The frame supporting both the cylinder and the rotative crank-shaft *b* is known as the *crank-case*. At *c* is shown the *crankpin;* at *d*, the *crank*, rigidly connecting *b* and *c*; at *e*, the *piston*, of the hollow, or *trunk*, type; at *f*, the *connecting-rod*, attached rotatively to both the crankpin *c* and the piston *e*; at *g*, the *piston pin*, or *wristpin*, which connects the piston and connecting-rod. When the engine is running, the piston *e* moves forwards and backwards in the cylinder in conjunction with the rotation of the crank. At *h* is shown the *cylinder head;* at *i*, the *combustion chamber*, or *compression space*, into which the piston does not enter; at *j*, an opening, or *port*, connecting the combustion space of the cylinder with a passage through which combustible mixture is brought in; at *k*, a valve for closing the port *j*; at *l*, a valve for closing the port *m*, which connects the combustion chamber and a passage through which the burned, or *exhaust*, gases

escape from the engine; and at *n*, a jacket in which water is circulated to keep the engine cool.

3. The end of the cylinder nearest the crank is called the *crank end*, while the other end is called the *head end*. The movement of the piston from the head end to the crank end is called the *forward*, or *outward*, *stroke;* the movement in the opposite direction is called the *return*, or *inward*, *stroke*.

The valves that admit the new charge of air and fuel to the cylinder are called *inlet*, or *admission*, *valves*, and those which permit the burned gases to escape are called *exhaust valves*. These will be described later.

4. The **charge** is a mixture of fuel and air taken in at one stroke of the engine. It varies according to the conditions of operation, and may sometimes be sufficient to fill the cylinder completely at atmospheric pressure, while at other times it may be reduced. The proportions of fuel and air may also vary from time to time.

5. The **exhaust gases**—sometimes called the **exhaust**—are the waste products of combustion that are expelled from the engine after having performed the work required.

6. The **compression space** is a portion of the cylinder into which the charge is compressed previous to ignition. It includes the entire space between the piston face and valves when the piston is in its position nearest the cylinder head. It is sometimes called the **clearance,** or **combustion, space.**

7. Definition of Cycle.—Any round of happenings consisting of a series of events or operations susceptible of indefinite repetition, and occurring regularly in the same order, is a **cycle.** The cycle on which an internal-combustion engine operates is one of the distinguishing features of different types. In order to make the meaning of the term cycle clear, one of the earlier methods of operating, now obsolete, will first be described.

In this earlier cycle, the piston, starting from its position nearest the cylinder head, was first pulled outwards away from the cylinder head by the action of the rotating crank. During a sixth of a revolution or so, corresponding approximately to one-third of the complete outward movement of the piston, combustible mixture was drawn into the cylinder, the valve *k*, Fig. 1, being kept open for this purpose. The valve *k* was then closed and the mixture immediately ignited by suitable means. The increased pressure due to combustion then drove the piston out during the remainder of the first half revolution, and the connecting-rod transmitted to the crank-shaft the mechanical energy, less some loss by friction, thus developed at the piston. At or about the end of this outward stroke of the piston, the valve *l* was opened, and the burned gases in the cylinder, still at a pressure higher than that of the atmosphere, escaped in part by expansion through the port *m*. The continued rotation of the crank-shaft through the remainder of its revolution forced the piston back into the cylinder to its initial position at the beginning of the outward stroke. This inward stroke of the piston expelled more of the burned gases through the port *m*, the valve *l* being kept open. At or about the end of the inward stroke the valve *l* was closed, and the valve *k* opened. These operations were then repeated indefinitely.

In this obsolete case, the cycle consisted of drawing in the charge of combustible mixture at an approximately constant pressure, about equal to that of the atmosphere; heating the gas by combustion; expanding the gas, with accompanying reduction of pressure; and, finally, discharging the still hot gases against the pressure of the atmosphere.

APPLICATION OF FOUR-CYCLE PRINCIPLE

8. The more modern cycle of automobile engines can be carried out with the engine shown in Fig. 1, by simply operating the valves in a different manner. The modern cycle is known as the **Beau de Rochas cycle,** after the name of the inventor, and more commonly as the **Otto cycle,**

after the name of the engineer who carried out its early commercial application. This cycle, in its broad and strictly scientific meaning, does not take into consideration the method of getting the charge of combustible mixture into the cylinder nor that of expelling the hot burned gases. The steps of the cycle are as follows, still referring to Fig. 1:

Suppose that, at the beginning of operations, the valves are closed, that the piston is at its position farthest out toward the crank-shaft, and that the cylinder is filled with a combustible mixture at atmospheric pressure. By forcing the piston inwards to the completion of the inward stroke, the charge will be compressed into the compression space, or combustion space, *i*. Now by igniting the compressed charge, the pressure will be increased still more by the heat of combustion. The pressure tends to drive the piston outwards, and as soon as the rotating crank-shaft has made the angle between the connecting-rod and crank sufficiently great, the pressure of the hot gases against the piston face will drive the crank-shaft. The burned gases expand to fill the increasing volume of the cylinder as the piston moves outwards and the pressure decreases. At the completion of the outward stroke, the exhaust valve is opened and the hot burned gases escape by expansion until the pressure falls to that of the atmosphere. This completes the Otto heat cycle.

9. The method of expelling the burned gases that remain in the cylinder at atmospheric pressure and of taking in a fresh charge of combustible mixture has not yet been considered. This is accomplished in two distinct ways, which are the foundations for the commercial names, *four cycle* and *two cycle*, as applied to automobile engines.

10. In the **four-cycle engine** the burned gases remaining in the cylinder after the exhaust valve has been opened and part of the hot gases removed by expansion are expelled in part by giving the piston another inward stroke. The exhaust valve is then closed. The piston then moves outwards and draws in a fresh charge through the mixture

inlet port. At the end of this last stroke the conditions are therefore again the same as assumed at first, and hence the cycle is complete. Four strokes are required for each explosion by this method of operating.

11. In the **two-cycle engine,** operating on the principle of the Otto cycle, a fresh charge of combustible mixture is forced into the cylinder while the piston is at or near its outward position, away from the cylinder head. This is done by slightly precompressing the charge before it enters the cylinder. With the arrangement of valves shown in Fig. 1, the engine, as illustrated, can in a way be operated as a two-cycle engine. To operate it in this manner, the exhaust valve is opened as usual at the end of the outward stroke, and as soon as the pressure of the hot gases has fallen nearly to that of the atmosphere, the mixture inlet valve is opened to admit the slightly precompressed mixture, whose pressure, of course, is higher than that of the atmosphere. As the fresh charge enters, it drives out part or all of the remaining burned gases; then both valves are closed. The burned gases are exhausted and the fresh charge is introduced while the piston is at or near its outward position. The complete series of operations is therefore accomplished during two strokes of the piston, corresponding to one revolution of the crank-shaft.

12. In the obsolete cycle first described, the complete cycle is also carried out during two strokes of the piston, yet the series of events is very different from those of the Otto cycle carried out during two strokes. There are also other cycles in commercial use that differ from the Otto but are carried out during either two strokes or four strokes of the piston. Therefore, the designations four cycle and two cycle, in relation to general internal-combustion-engine practice, are not absolutely definite. A clear method of designating engines operating on the Otto cycle is by the terms *four-stroke Otto-cycle engine* and *two-stroke Otto-cycle engine*. However, since practically all automobile engines of the internal-combustion class operate on the Otto cycle, as

already stated, the terms four cycle and two cycle are sufficiently definite in meaning when limited to this field of application.

13. Compressing the Charge.—In the obsolete cycle, the charge of combustible mixture was not compressed. The air was drawn in directly from the atmosphere and the gas or vapor mixed with it just before entering the engine cylinder. Consequently, the pressure of the charge in the cylinder at the instant of ignition was low; it is generally lower than that of the atmosphere. It was found later that by compressing the charge before igniting it, as has been described, a greater amount of mechanical power could be obtained from a given quantity of fuel. In other words, the efficiency of the internal-combustion engine is increased by compressing the charge before igniting it.

There are certain phenomena incident to the compression of a combustible mixture that limit the intensity to which the pressure can be raised when the rate of compression is as rapid as is customary in automobile-engine practice. The causes limiting the extent of compression will be discussed later. All internal-combustion automobile engines compress the charge before igniting it, assuming that all of them operate on the Otto cycle.

14. Distribution of Heat Energy.—The heat energy of the fuel liberated by combustion is transformed in part into mechanical energy, or mechanical power, at the piston and then transmitted, with some frictional loss, to the crank-shaft of the engine. The remainder of the heat energy of the fuel is wasted so far as the performance of mechanical work, or the delivering of mechanical power, by the engine is concerned. Of the lost portion of the heat, part is carried out by the expelled gases of the exhaust and part is abstracted from the burning and expanding charge by the enclosing walls of the cylinder, piston, and other parts with which the hot gases come into contact before the exhaust port is opened; also, part of the mechanical energy received by the piston from the expanding gases is lost in the frictional resistance

to the motion of the piston and other moving parts of the engine. The part of the mechanical energy that is lost by friction is transformed back into heat energy, and, together with that abstracted from the hot gases by the enclosing walls, is lost by radiation or carried away by the water, other liquid, or air used to keep the engine cool.

Some of the mechanical energy received by the rotating parts of the engine during the impulse, or driving, stroke of one combustible charge is used to compress the following charge. Compressing the charge heats it. Thus, another portion of the mechanical energy developed during the expansion of the burned gases of one charge is retransformed into heat energy in the following combustible charge.

15. That compressing the charge heats it, can readily be shown with an air pump, such as is commonly used for inflating pneumatic tires. To show the heating effect, first remove the connections of the air pump so that the passage through which the compressed air escapes from the compression space of the pump to the atmosphere is short; then operate the pump and hold a finger or thumb over the outlet so as to let the compressed air escape at considerable pressure. The heat of the compressed air will be decidedly noticeable if the pumping is done rapidly. If the pumping is not rapid, a large part of the heat of the air will be given up to the metal of the pump.

The cooling of the air by expansion can be demonstrated by allowing compressed air to escape through a small opening, as a petcock, from a tank in which the compressed air has been allowed to cool to the temperature of the atmosphere. A thermometer held in the outside escaping current at a short distance from the outlet will show a lower temperature than that of the atmosphere.

PARTS AND OPERATION OF FOUR-CYCLE ENGINE

16. Parts of Engine.—A sectional view of a four-cycle gasoline engine, such as is used on automobiles, is shown in Fig. 2. At *a* is shown the cylinder; at *b*, the cylinder head; at *c*, the piston; at *d*, the piston pin, or wristpin; at *e*, the crank-shaft; at *f*, the crank; at f_1, the crank-pin; at *g*, the connecting-rod; at *h*, the inlet, or admission, port through which the combustible charge of mixture enters the cylinder; at *i*, the passage through which the charge flows into the port *h*; at *j*, the inlet, or admission, valve, approximately disk-shaped, which closes the inlet passage at the proper time; at j_1, the valve seat on which the valve *j* rests when closed; at *k*, the inlet-valve stem, rigidly attached to and forming part of *j*; at *l*, a coiled compression spring that holds the valve *j* closed, except at such times as it is forcibly opened to admit a charge to the cylinder; at *m*, the lifting rod, push rod, or thrust rod, that lifts the valve *j*; and at *n*, the inlet cam rigidly attached to the inlet cam-shaft *o*, also called the *half-speed shaft*, or *lay shaft*. As the inlet cam *n* rotates, its projection, or lobe, bears against the roller

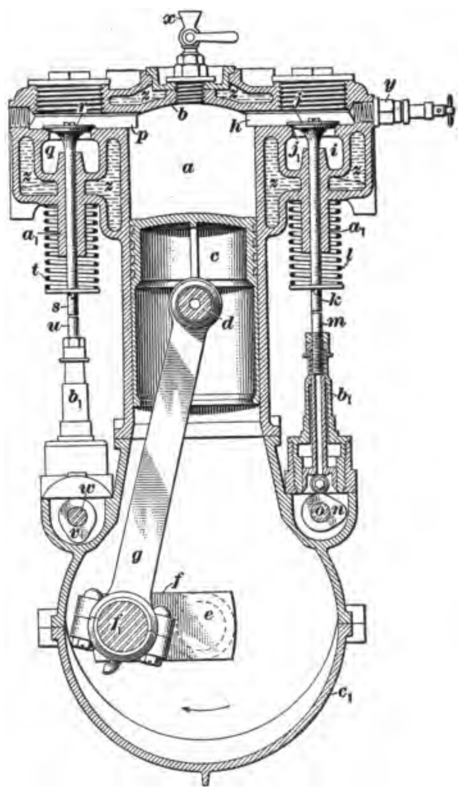


FIG. 2

at the lower end of the push rod *m* and lifts the rod, which in turn lifts the inlet valve *j*. The burned gases escape from the cylinder through the exhaust port *p* into the passage *q* and thence to the atmosphere. The exhaust valve *r* closes the exhaust passage except at such times as it is forcibly opened to release the burned gases. At *s* is shown the exhaust-valve stem; at *t*, the exhaust-valve closure spring; at *u*, the exhaust-valve push rod; at *v*, the exhaust-valve cam; at *w*, the exhaust-valve cam-shaft; at *x*, a compression-relief cock, or petcock, with funnel top; at *y*, the spark plug; at *z*, the space for cooling water, which forms a water-jacket to keep the cylinder and adjacent parts from becoming too hot; at a_1, valve-stem guides; at b_1, push-rod guides; and at c_1, the crank-case.

17. Operation of Engine.—The operation of the four-cycle type of automobile engine is as follows, starting with the piston in its position nearest the cylinder head, as shown in Fig. 2, and the space between the piston and valves filled with air or burned gases at atmospheric pressure:

First Stroke.—The piston, following the motion of the crank-shaft, moves downwards on the first out stroke; this tends to produce a partial vacuum in the upper part of the cylinder. The inlet valve *j* is forcibly opened at, or slightly after, the time the piston starts on its outward stroke. The reduced pressure, or *suction*, in the cylinder draws combustible mixture into the cylinder during the complete outward stroke of the piston. The exhaust valve is kept closed during this charging stroke. The inlet valve is allowed to close by the action of its spring at, or shortly after, the completion of the outward stroke of the piston. This movement of the piston is variously known as the *charging stroke*, *admission stroke*, *inlet stroke*, *suction stroke*, and *induction stroke*.

Second Stroke.—The piston, still driven by the crank-shaft, moves upwards on the inward stroke and compresses the charge into the space *a* above the piston. Both valves remain closed during this compression stroke. The charge is ignited by an electric current that is passed through the spark plug

at about the time that the compression stroke is completed, but generally just before the completion of the compression stroke.

Third Stroke.—Combustion is completed, and the pressure against the piston face drives it outwards again on a second outward stroke, called the *working stroke*, *impulse stroke*, *explosion stroke*, or *combustion stroke*. Both valves remain closed from the beginning to nearly the end of the impulse stroke. The exhaust valve is opened mechanically just before the completion of the stroke, and part of the burned gases escape into the atmosphere, so that the pressure in the cylinder falls nearly as low as that of the atmosphere. The exhaust valve is opened against the resistance of both its closing spring and the gas pressure in the cylinder. This opening of the exhaust valve is accomplished by the action of the cam *v* during its rotation, which is at half the speed of that of the crank-shaft.

Fourth Stroke.—The piston, driven by the crank-shaft, moves upwards on a second inward stroke and expels part of the burned gases from the cylinder. This is generally known as the *exhaust stroke*—less commonly, as the *eduction stroke*, or *ejection stroke*. The space *a* that forms the combustion chamber remains filled with the burned gases at the completion of the exhaust stroke. The pressure of these residual gases is generally about the same as, or somewhat higher than, that of the external atmosphere. The exhaust valve is sometimes set to close just at the end of the exhaust stroke, but usually not until shortly after the completion of the exhaust stroke. The completion of the exhaust stroke ends the cycle of operations, which are repeated again and again.

18. The various steps in the operation of the four-cycle type of automobile engine and the corresponding positions of the valves are illustrated in Fig. 3. In (*a*) is shown the suction stroke with the inlet valve open; in (*b*), the compression stroke with both valves closed; in (*c*), the impulse stroke with both valves still closed; and in (*d*), the exhaust stroke with the exhaust valve open.

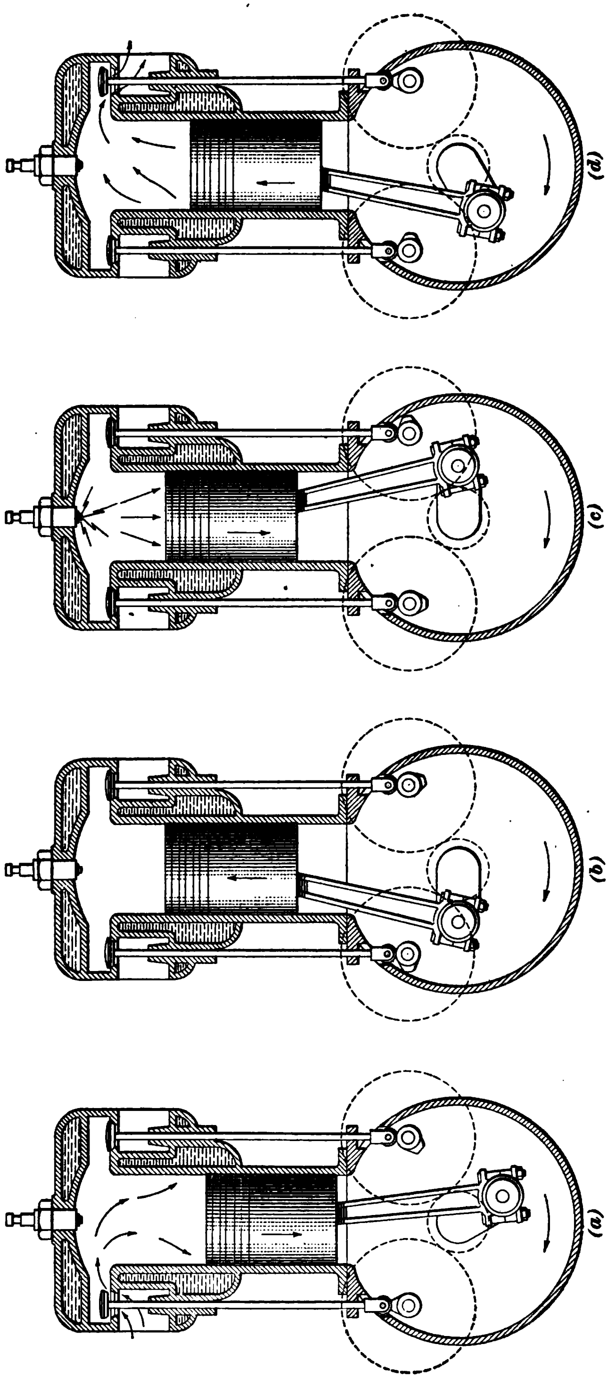


Fig. 3

TYPICAL AUTOMOBILE ENGINES

GENERAL CHARACTERISTICS

ARRANGEMENT OF FOUR-CYCLE ENGINE CYLINDERS

19. The typical automobile engine has from one to four cylinders, which may be horizontal or vertical, is small and compact, is of light weight, and is run at high speed. The maximum power of single-cylinder engines at present in use in the United States is about 10 horsepower, and four-cylinder engines are built as small as 10 or 12 horsepower. The compression pressure under which they are operated is from

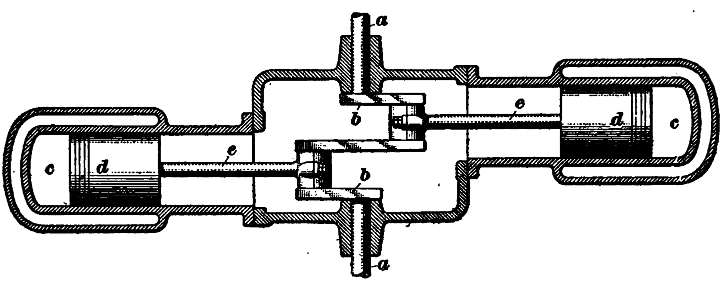


FIG. 4

medium to high, and some sort of a float-feed carbureter is generally employed. The inlet valve is sometimes automatic, and sometimes mechanically operated; the latter type predominates. The engine is controlled almost exclusively by hand throttling of the ingoing charge and variation of the time of ignition. Some of the engines of higher power have centrifugal governors, in which the governing action depends on the centrifugal force of rotating weights and may be modified by the operator as desired, to increase or retard the speed of the engine. The charge is ignited by electric spark.

Single-cylinder horizontal and vertical engines are used in the smaller, single-seat automobilies, known as *runabouts*.

20. Cylinders of a Double-Opposed Engine.—In a two-cylinder four-cycle horizontal engine, the cylinders are nearly always located, relatively to each other, as shown in Fig. 4. The two cylinders are placed on opposite sides of the crank-shaft *a*, and the cranks *b* are at an angle of 180° from each other. A two-cylinder engine with opposed cylinders *c* is generally known as a **double-opposed engine.** The cranks are also referred to as being opposite to each other.

By this arrangement of cylinders, the explosions and consequent impulses on the piston occur every revolution, first in one cylinder and then in the other. While one of the pistons *d* is on its impulse stroke, the other is on its suction stroke. The cycles of the two cylinders may be said to be out of phase, that is, out of synchronism, with each other by one-half of a cycle, corresponding to one revolution of the crank-shaft.

Both pistons move toward the crank-shaft at the same instant and with the same speed; they also recede from the crank-shaft at the same time, each having the same speed of travel at any given instant. They are therefore balanced in their motion, except for a slight tendency to move sidewise because of the fact that they are not exactly opposite each other. If the two pistons and their connecting-rods *e* were exactly opposite each other, one rod end being yoked so as to straddle the other, this tendency to side motion would be completely eliminated. Hence, it is desirable to have the pistons as nearly in line as possible, in order to reduce vibration to the smallest amount. With most automobile engines of this type, however, there is very little vibration due to lack of complete balancing.

21. Twin Cylinders.—In a small proportion of automobile engines of the four-cycle two-cylinder type, the cylinders are placed side by side. This arrangement is seldom found except in vertical engines. In Figs. 5 and 6 are shown the main parts of two-cylinder engines with the

cylinders forming one integral part. When the cylinders are thus cast together they are called **twin cylinders.**

22. In Fig. 5 the cranks are 180° apart and the pistons consequently move in opposite directions. The moving parts, pistons, and connecting-rods are thus fairly well balanced. The impulses, however, occur irregularly. The time interval between the impulses is first one-half revolution of the crank, and then one and one-half revolutions of the crank. This is three times as great an interval in one case as in the

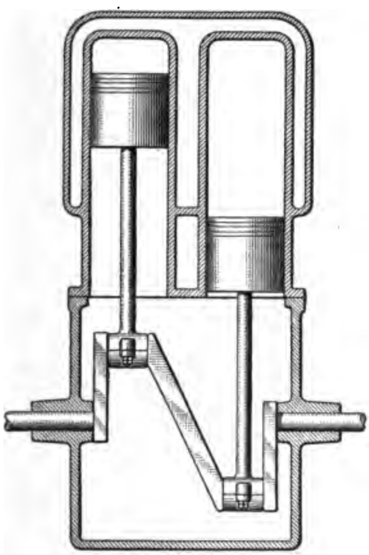


FIG. 5

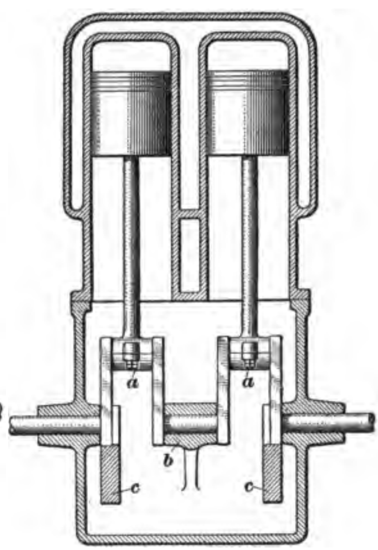


FIG. 6

other. This irregularity of time between explosions is generally considered an objectionable feature in this type of engine. If the moving parts are well balanced, the irregularity is generally not noticeable, except in the sound of the exhaust. But, occasionally, when the engine is running at rather slow speed and pulling hard, a somewhat jerky motion is transmitted to the automobile and thus sets up a vibration in its parts.

23. In Fig. 6 the two cranks are placed on the same side of the crank-shaft, the angle between the cranks being zero in this case; that is, the axes of the crankpins *a* are in line with each other. This arrangement secures an equal time interval of one revolution between impulses. The pistons move in unison, and it is therefore extremely difficult, even with balance weights *c*, to balance the moving parts so as to prevent serious vibration in the automobile. If the engine is small, the center bearing *b* is dispensed with, both connecting-rods being attached to the same crankpin.

24. Neither of the two preceding types of four-cycle two-cylinder engines with the cylinders on the same side of the crank-shaft is used very much for pleasure vehicles fitted with vertical engines. They find somewhat more general, though not extended, application as horizontal engines for driving commercial trucks.

25. Engines With Four Cylinders.—In a four-cylinder four-cycle engine of the vertical type, all the cylinders are generally located on one side of the crank-shaft, with all their axes in the same plane, as shown in Fig. 7, which is a diagrammatic illustration of a vertical four-cylinder four-cycle engine, showing the relative positions of the piston.

Three bearings *a*, *b*, and *c* support the crank-shaft. The cranks of the two end pistons are at an angle of 180° with those of the two middle pistons. The end pistons therefore move in unison and in a direction opposite to the motion of the two middle pistons. The power impulses occur every half revolution in a four-cylinder four-cycle engine thus arranged. The impulses in the end pair of cylinders alternate with those of the middle pair.

Four-cylinder four-cycle engines are also made of the horizontal-opposed type. Two cylinders are placed side by side on each side of the crank-shaft. Such engines find little use in pleasure cars, but are not uncommon in commercial vehicles.

26. The *order of explosions*, referring to the numbers in the cylinders, Fig. 7, may therefore be either *1–3–4–2* or *1–2–4–3*. If the order of the impulses is *1–2–4–3*, and cylinder *1* is on the impulse stroke, then *2* is compressing, *3* is exhausting, and *4* is drawing in a fresh charge.

As the two middle pistons move in unison and in a direction opposite from that of the two end pistons, the whole system of moving parts is well balanced. There is practically no tendency for the moving parts to twist the crank around

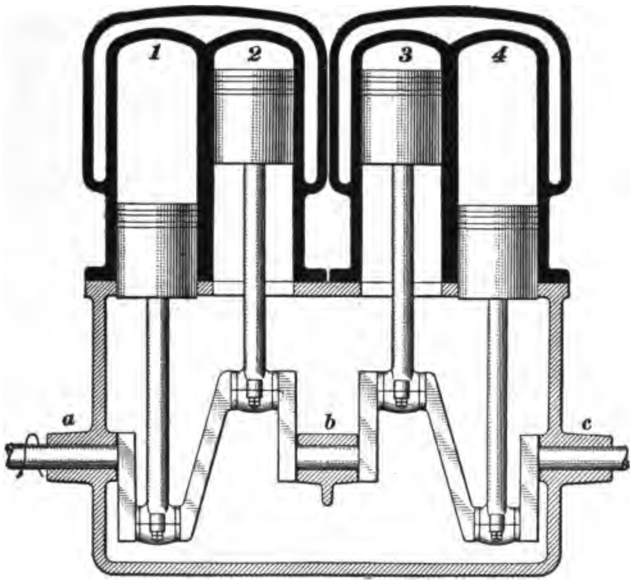


Fig. 7

sidewise, as in the case of the double-opposed engine shown in Fig. 4.

That the order of firing must be as indicated will be apparent by referring to Fig. 7. The arrangement of the crankshaft is such that, while the pistons in cylinders *1* and *4* are descending on their working and suction strokes, respectively, the pistons in cylinders *2* and *3* are moving upwards on their compression and exhaust strokes. Representing the working, exhaust, suction, and compression strokes necessary to

complete a cycle by the letters *W*, *E*, *S*, and *C*, the following diagrams, Fig. 8 (*a*) and (*b*), will serve to illustrate how the movement of the exhaust valves makes it possible to determine the order of firing, which is dependent on the operative relations between cylinders *2* and *3*; that is to say, whether the compression or the exhaust stroke is to take place in cylinder *2* or in cylinder *3* when the order of events in cylinders *1* and *4* are as indicated. At the top of the diagrams, Fig. 8 (*a*) and (*b*), the numbers of the cylinders corresponding to the numbering in Fig. 7 are given. The arrows just below the numbers indicate the initial direction of movement of the pistons, and the figures at the left indicate the number of degrees of travel of the cranks necessary to carry the pistons to the beginning of the strokes represented by the letters *W*, *E*, *S*, and *C*, the beginning of the working stroke, or point at which the charge is fired in cylinder *1*, being taken as zero.

	1	2	3	4
	↓	↑	↑	↓
0°	*W*	*C*	*E*	*S*
180°	*E*	*W*	*S*	*C*
360°	*S*	*E*	*C*	*W*
540°	*C*	*S*	*W*	*E*
720°	*W*	*C*	*E*	*S*

(*a*)

	1	2	3	4
	↓	↑	↑	↓
0°	*W*	*E*	*C*	*S*
180°	*E*	*S*	*W*	*C*
360°	*S*	*C*	*E*	*W*
540°	*C*	*W*	*S*	*E*
720°	*W*	*E*	*C*	*S*

(*b*)

Fig. 8

27. To complete a cycle in any one cylinder, the crank must travel 720°, or two revolutions; but, as there are four cylinders, the crank-shaft receives four power impulses during two revolutions, and hence, in order that the application of power may be uniform, the impulses must occur 180° apart. Fig. 8 (*a*) shows that, when the working stroke in cylinder *2* begins at 180°, it will be necessary to fire the charge in cylinder *4* at 360°, following with cylinder *3* at 540°, the cycle being completed just at the point where an explosion is about to take place in cylinder *1* at 720°, or two complete revolutions. With this arrangement, the order of firing is shown to be *1–2–4–3*. Fig. 8 (*b*), however, shows that,

when the second power impulse takes place at 180° in cylinder *3*, the order of firing must be *1–3–4–2*.

28. Engines With Six Cylinders.—Six-cylinder four-cycle vertical engines are much the same in form as the usual type of four-cylinder engines. The six cylinders are placed in a row above the crank-shaft. The cranks may be considered as being in pairs, the cranks of a pair having no angle between them; that is, both are on the same side of the crank-shaft and in the same plane. The two cranks of a pair may be either adjacent to each other or separated by other cranks interposed between them. The three pair of cranks are at an angle of 120° with each other, corresponding to one-third of a revolution.

The impulses occur at intervals of one-third of a revolution; therefore, there are three impulses per revolution. If the pairs of pistons moving in unison are called *1*, *2*, and *3*, then the impulses occur in one cylinder of each pair in the order *1–2–3*, according to the pair number, and then again in the order *1–2–3* in the remaining cylinder of each pair.

The arrangement of the crank and the shafts in six-cylinder engines varies greatly in different makes of engines. It is somewhat common, however, for the first and sixth cylinders to have their cranks as a pair, the second and fifth as a pair, and the third and fourth as a pair. By this arrangement there is no tendency to turn the shaft sidewise on account of lack of balancing the moving parts. However, other arrangements of cranks on the shaft are not by any means uncommon.

29. Engines With Three Cylinders.—Three-cylinder four-cycle vertical engines with the cylinders arranged in line above the crank-shaft, as shown in Fig. 9, were used for a while on automobiles, but they have been practically discarded. The cranks were placed at an angle of 120°, corresponding to one-third of a revolution, with each other. The apparent chief reason for discarding this type of engine was inability to secure satisfactory balancing of the moving parts without the aid of heavy counterweights on the cranks. Even when counterbalance weights were used, the balance

was not as nearly perfect as can be secured in the vertical four-cylinder and the double-opposed engines of the types that have been described.

ARRANGEMENT OF TWO-CYCLE ENGINE CYLINDERS

30. A two-cylinder two-cycle engine usually has its cylinders side by side, as in Fig. 5, and the cranks at an angle of 180° apart, corresponding to one-half revolution. The impulses occur every half revolution. The moving parts can be well balanced in this disposition of the parts, as has already

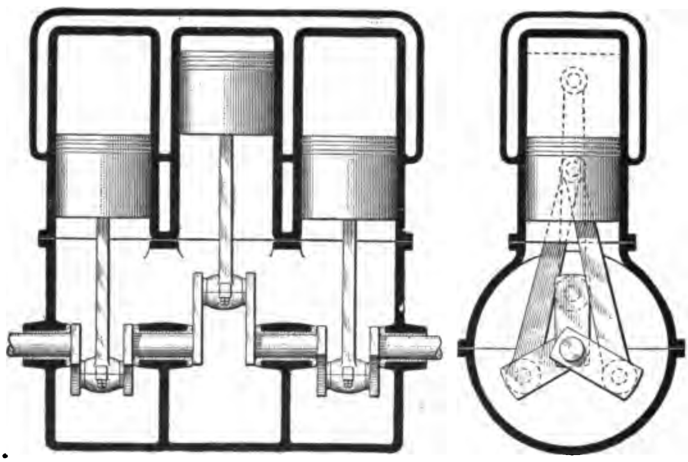


FIG. 9

been stated. The engines are made in both horizontal and vertical types.

31. Three-cylinder two-cycle engines are generally arranged as shown in Fig. 9. The cranks are 120° apart, so that the impulses occur every third of a revolution. The three-cylinder engine has found greater favor in the two-cycle type than in the four cycle. This is probably due to the fact that, although the same mechanical conditions exist regarding the balancing of the moving parts as in the four-cycle engine, the difference in the operations performed

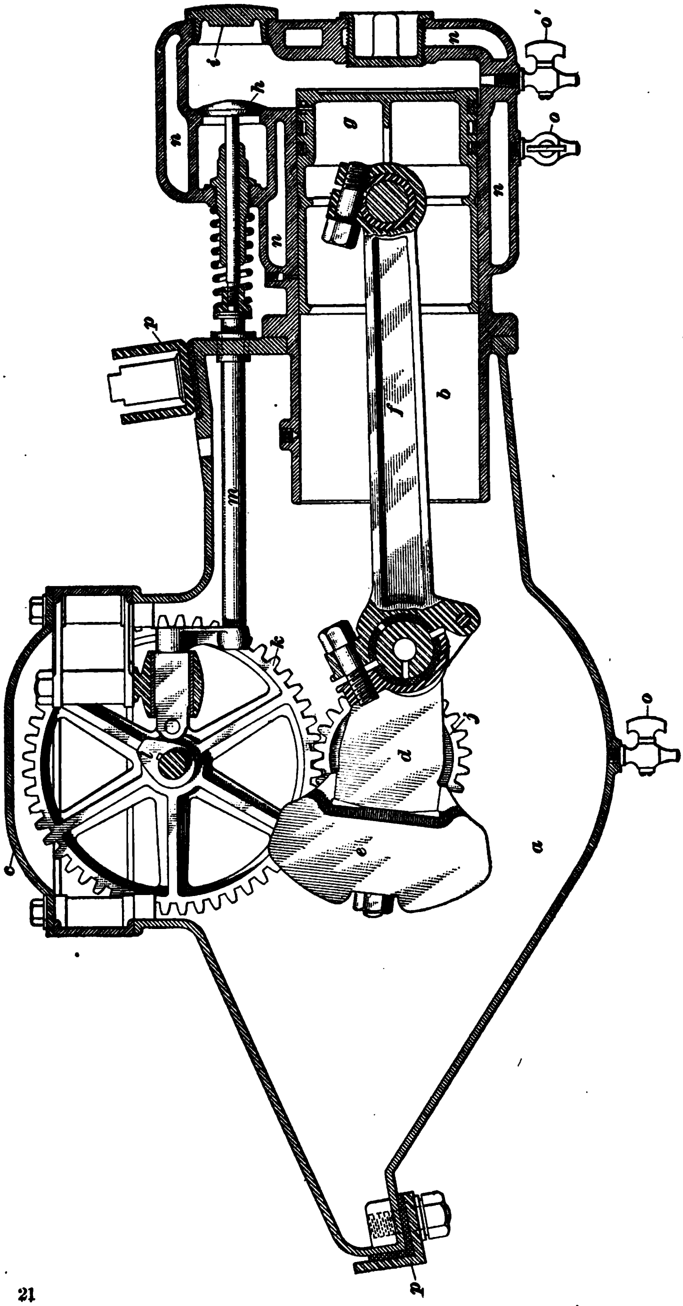


Fig. 10

by the piston apparently accounts for the more satisfactory service of the three-cylinder two-cycle engine. Any one piston of the two-cycle engine compresses a charge and receives an impulse every revolution, which is a uniform method of working as compared with the alternate outward suction and impulse strokes, and also the alternating inward exhaust and compression strokes of the four-cycle engine.

32. The four-cylinder two-cycle engine generally has all its cylinders in line on one side of the crank-shaft, as shown in Fig. 7, but the cranks are placed 90° apart, corresponding to one-quarter revolution, instead of 180° as shown in the figure. The impulses occur every quarter revolution.

33. The double-opposed engine, Fig. 4, and the twin-cylinder engine with pistons moving in unison, as shown in Fig. 6, are not suitable types for two-cycle engines, because the impulses in each of these types would occur simultaneously in the two cylinders, once every revolution.

FOUR-CYCLE WATER-COOLED ENGINES

SINGLE-CYLINDER TYPES

34. Horizontal Engines.—The parts of the horizontal type of single-cylinder four-cycle water-cooled automobile engine are shown in Fig. 10. At *a* is shown a crank-case enclosing the end of cylinder *b*. This case is provided with a cover *c*, which can be removed when it is desired to inspect the enclosed parts. The crank *d* carries a counter-weight *e* for the purpose of balancing, as far as possible, the connecting-rod *f* and reciprocating piston *g*. The piston is of the trunk type and is made long so as to obtain ample bearing surface against the cylinder and to prevent its canting and binding in the cylinder. It is ribbed at the head to secure strength and yet make it as light as possible. The inlet and exhaust valves are mechanically operated; only one of them, *h*, is shown. This valve is taken out for replacement or

grinding by unscrewing the plug *i*. The valves *h* are opened by means of the pinion *j* on the crank-shaft and gear *k* and cams *l* on the cam-shaft, the motion being transmitted to the valves through push rods *m*. The gear *k* has twice as many teeth as the pinion *j*, and therefore rotates only half as fast. The shaft to which it is attached is sometimes called the *half-time shaft*, the pinion *j* and gear *k* together being known as the *two-to-one gears*. The rods are guided at both ends in bearings, and are offset, as shown, for the purpose of bringing the rods in line with the valves. The end of *m* on which the cam acts carries a small case-hardened steel roller. Periodically during the rotation of the cam *l*, its projection, or lobe, bears against the roller in the end of the push rod and forces the rod back so as to lift the valve.

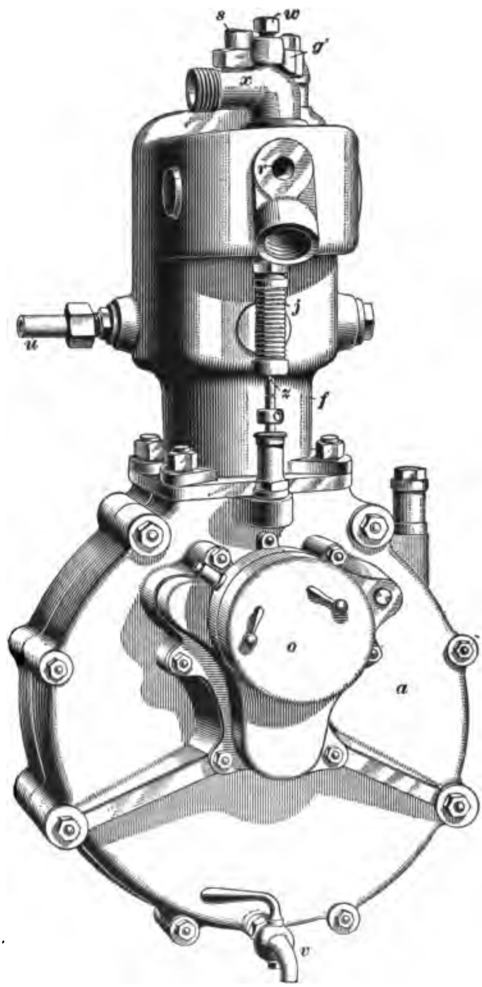


FIG. 11

This occurs only once every two revolutions of the crank-shaft, corresponding to four strokes of the piston. The angular width of the cam-lobe, measured circumferentially as an arc of a circle,

is such that the valve is held open during the proper period of time and then allowed to close by the action of the valve spring. At *n* is shown the water-jacket; at *o*, the drainage cocks; and at *o'*, a compression relief cock for relieving compression in the cylinder when starting the engine by hand and for draining oil or other liquid from the cylinder. The engine is suspended at the points *p* from cross-members of the frame of the automobile chassis.

35. Vertical Engines.— The external view, Fig. 11, and sectional elevation, Fig. 12, illustrate a type of small vertical single-cylinder engine in which the crank-case is enclosed and is large enough to contain the flywheels, which, although small in diameter, are quite heavy. The crankpin is made with a taper fit in the flywheels, which are thickened where the pin passes through, and the two halves of the crank-shaft are also made with taper fits in the flywheel hubs, and are further secured by keys. The flywheels are steel castings, and opposite the crankpins they have counterweights cast on them inside the rim. Engines of this kind are run at very high speeds; and in order to do this without undue mechanical vibration, the piston and connecting-rod are made as light as possible.

In these illustrations, at *a* is shown the crank-case, divided vertically and bolted together by through bolts; at *b*, the piston; at *c*, the connecting-rod; at *d*, the crankpin; at *e*, the flywheels; at *f*, the cylinder; at *g*, the water-jacket; at *h*, the inlet valve; at *i*, the exhaust valve; at *j*, the exhaust-valve spring; at *k*, the exhaust-valve cam; at *l*, the two-to-one gear; at *m*, the two-to-one pinion; at *n*, the end of the crank-shaft, tapered to receive a driving pinion by which the power of the engine is transmitted; at *o*, an aluminum cover enclosing the portion of the ignition system that closes the electric circuit at the proper time for ignition, called the *ignition timer*, *spark timer*, or simply the *timer;* at *p*, the rotating part of the timer—called the *rotor* of the timer—attached to and rotating with the cam-shaft, and made so as to close the electric circuit once every two revolutions of the

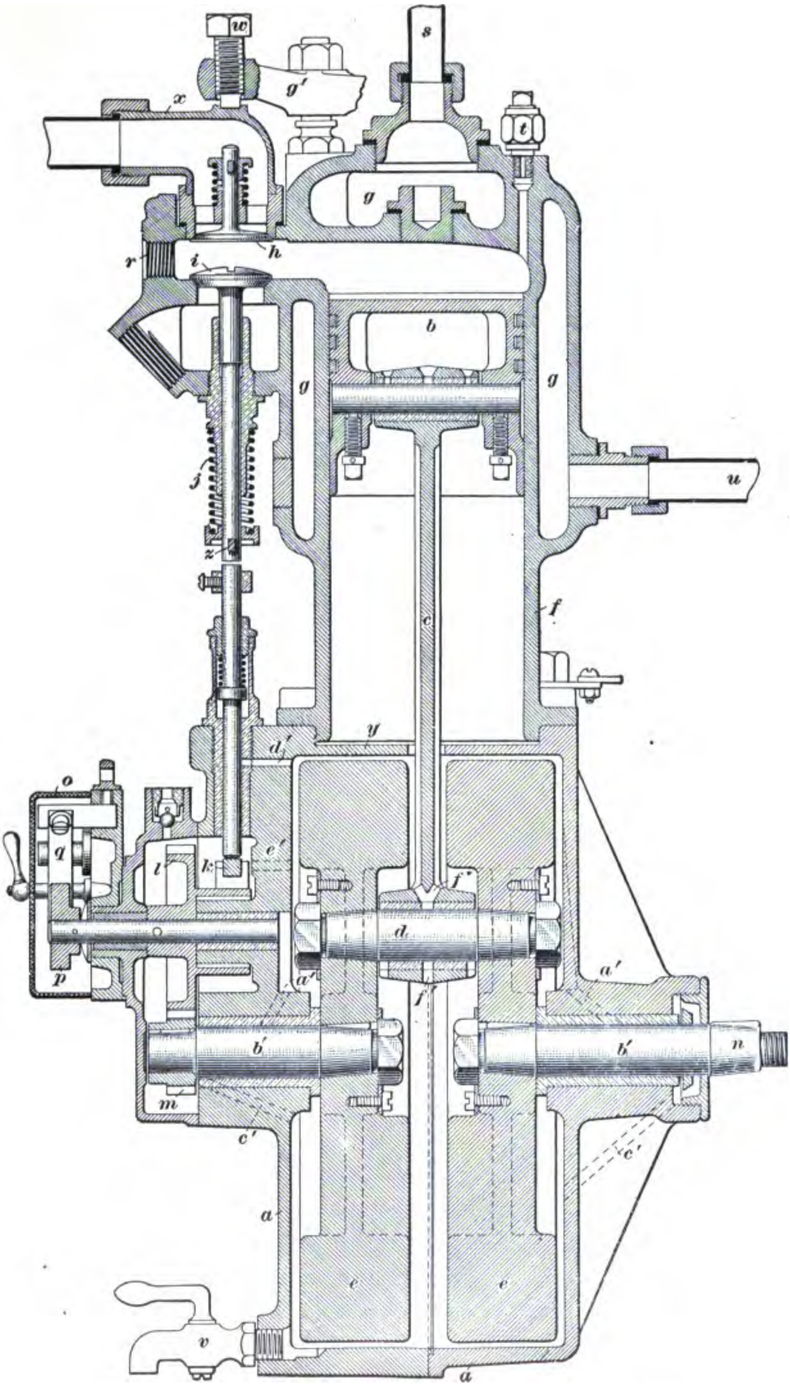


Fig. 12

crank-shaft; at *q*, the contact spring of the spark timer; at *r*, a threaded hole into which the spark plug is screwed; at *s*, the outlet for circulating cooling water; at *t*, a relief cock for relieving compression in starting; at *u*, the jacket-water intake; at *v*, a drainage cock for emptying the crank-case of oil; at *w*, a setscrew that holds down the elbow casting *x*; at *y*, a baffle plate to prevent an excess of oil from being thrown from the flywheels into the cylinder; and at *z*, the exhaust-valve stem key.

Access to the exhaust valve *i* is had by taking out the inlet valve and turning to one side the yoke *g'*, in which the setscrew *w* is held. Then, by slightly compressing the exhaust-valve spring, the key *z* may be slipped out, thus freeing the valve from its spring *j*.

The casting *x* holds down the inlet-valve cage against the force of the explosion, which tends to drive it out. By slackening the screw *w* and lifting off *x*, the inlet-valve cage, with the valve attached, can be lifted out for inspection or regrinding of the valve.

36. As indicated, the engine is equipped with an automatic inlet valve of the same general form as the mechanically operated poppet exhaust valve, but its stem is much shorter. A correspondingly short spring is used for closing it. This spring is weaker than the one on the exhaust valve, and consequently exerts a smaller force to press the valve against its seat. The operation of the valve during the charging, or suction, stroke is as follows: The piston moves downwards on the outward stroke, producing a partial vacuum in the upper part of the cylinder and reducing the pressure against the lower face of the inlet valve. The combustible mixture in the space above the inlet valve is at about atmospheric pressure. This atmospheric pressure above the inlet valve forces the latter open when the pressure below the valve is sufficiently reduced by the outward movement of the piston, and the combustible mixture then flows past the valve and on into the cylinder. In other words, the valve is opened and the mixture drawn in by suction. The exhaust valve is kept

closed by its stronger spring, as compared with that of the inlet. The inlet valve is closed by the action of its spring at or about the time that the piston completes its stroke. Otherwise, the operation of the engine is practically the same as that of one with both inlet and exhaust valves mechanically operated.

37. The parts of the engine shown in Figs. 11 and 12 are lubricated by what is known as the *splash system*, by which a quantity of oil is held in the lower portion of the crank-case, and the crank, as it rotates, throws the oil to the working surfaces. As the flywheels extend to the bottom of the case, it is sometimes necessary, in order to prevent the oil from being thrown up into the cylinder in excessive quantities, to provide the baffle plate *y*, Fig. 12, which intercepts all the oil except that which goes up through the slot in which the connecting-rod works.

Part of the oil running down the upper half of the crank-case is caught by the oil holes *a'* shown in dotted lines, and conducted to the centers of the crank-shaft bearings *b'*. A part of this oil works inwards, and the portion that works out to the outer end of the bearings is thrown off by the two-to-one pinion *m* at one end, and by the centrifugal oil ring shown on the other end of the shaft, and is carried back to the crank-case by the return holes *c'* shown below the bearings in dotted lines. At the top of the crank-case a lateral oil hole *d'* leads to the push rod of the exhaust valve *i*, and a little lower down is another hole *e'*, shown in dotted lines, that carries oil to the cam *k*. Oil reaches the crankpin through the oil holes *f'* in the large end of the connecting-rod, and a small amount of oil spray reaches the wristpin in the same way.

DOUBLE-CYLINDER TYPES

38. Horizontal Two-Cylinder Engines.—A double-opposed horizontal four-cycle water-cooled automobile engine is shown in horizontal section in Fig. 13. The cylinders *a*, bolted to the crank-case *b*, are offset as shown, necessitating

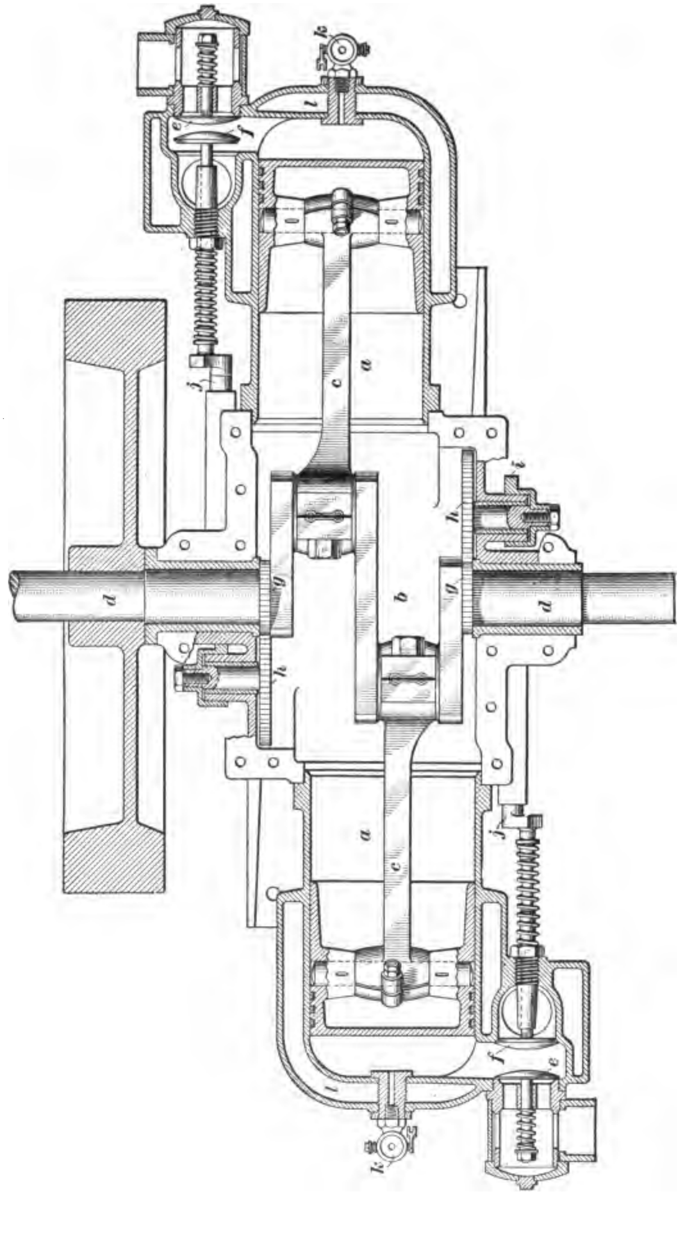


FIG. 13

an offset in the connecting-rods *c*. The crank-shaft is of the usual type, with the cranks 180° apart. Each of the automatic inlet valves *e* is placed opposite the corresponding exhaust valve *f*. The seat of each inlet valve is part of a valve cage that is removable with the inlet valve. The valve cage is held in place by a clamp (not shown). After removing the inlet valve and its cage, the exhaust valve can be taken out through the opening provided for the inlet valve and its cage.

Each of the exhaust valves *f* is operated by a separate cam driven by gears *g* and *h*, one of the cams being shown at *i*. These cams have separate shafts. Each cam against which the roller of the exhaust-valve push rod *j* pushes has its own pair of driving gears *g* and *h*, of which *h* on the cam-shaft has twice as many teeth as the driving gear *g*. This duplication of cam-shafts and gears is not usually found in automobile engines of this type. It is avoided by placing the valves either above or below the cylinders, instead of at the sides as illustrated. The usual practice is to place the valves above the cylinders rather than below them. Only one cam-shaft is then used, and in some designs, with all the valves mechanically operated, one cam serves to operate two valves, either both inlet valves, or both exhaust valves. Only two cams are therefore required for four mechanically operated valves. Engines of the latter type cannot generally be illustrated in section in a manner to bring out clearly in a single illustration the relation of their more important parts. Compression relief cocks *k*, mounted in a bushing that passes through the cylinder water-jackets *l*, are provided for relieving the compression pressure in starting. The structural elements of this engine are similar to those of the engines previously described, and hence no extended discussion of operation or construction is necessary.

39. Vertical Two-Cylinder Engines.—With vertical engines having more than one cylinder, it is customary to locate the inlet and exhaust valves at one side of the cylinders, as shown in Figs. 14 and 15, which are, respectively, an

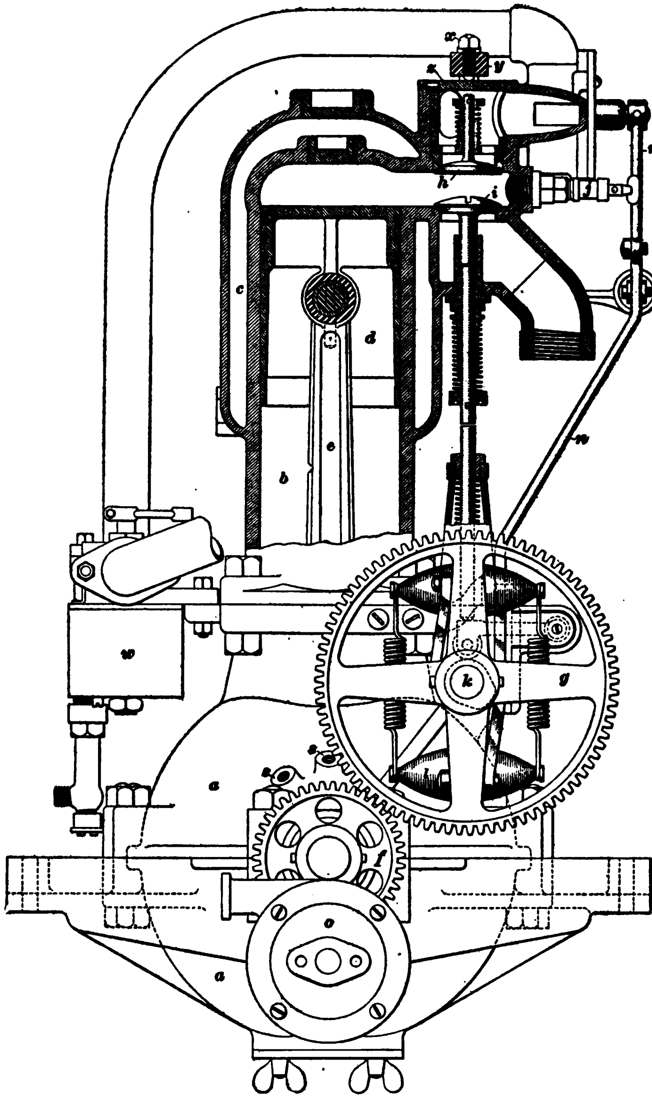


Fig. 14

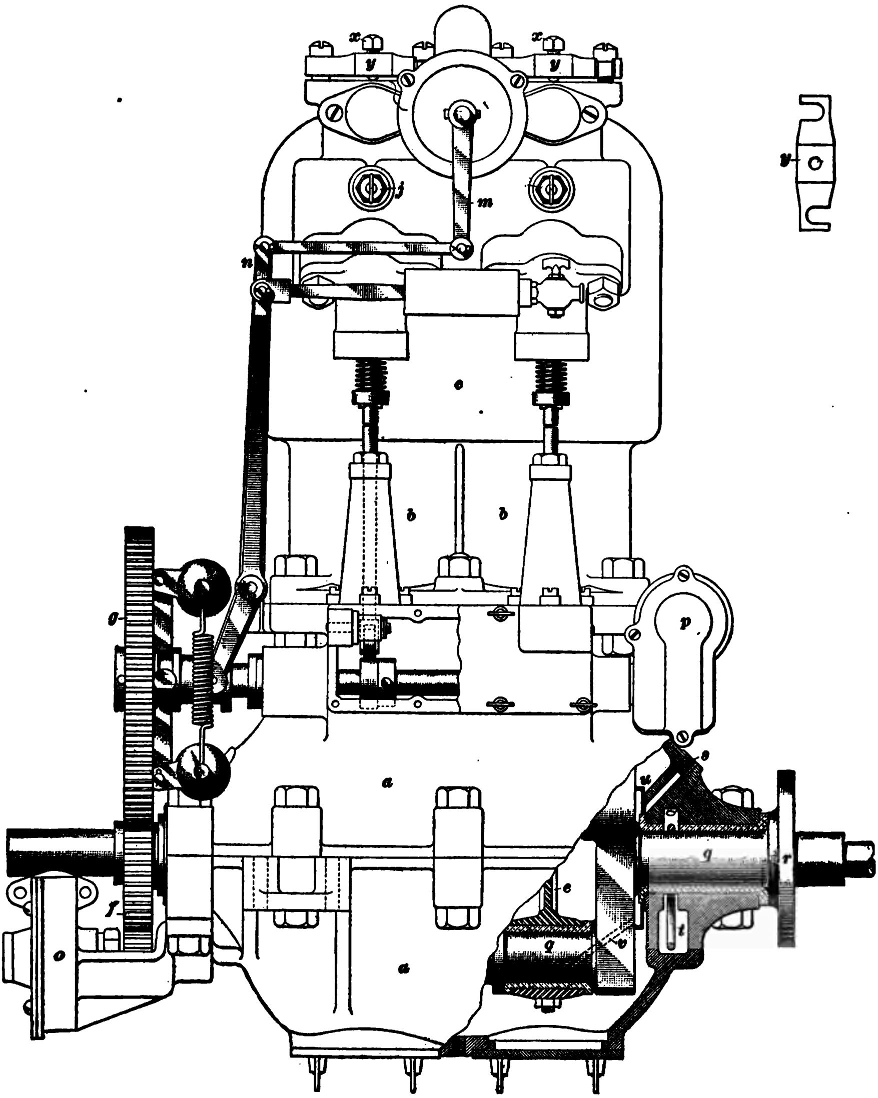


FIG. 15

end view and a side view of a vertical double-cylinder engine. Both views are partly in section. At *a* is shown the crank-case, divided horizontally in the plane of the crank-shaft; at *b*, the cylinder; at *c*, the water-jacket; at *d*, the piston; at *e*, the connecting-rod; at *f* and *g*, two-to-one pinion and gear; at *h*, the inlet valve; at *i*, the exhaust valve; at *j*, the spark plug; at *k*, the cam-shaft; at *l*, the centrifugal governor, which acts on the throttle lever *m* through the long lever *n*; at *m* and *n*, the lever mechanism that controls the throttle valve; at *o*, a centrifugal circulating pump, for circulating the water through the water-jacket, driven by a pinion meshing with the two-to-one pinion; at *p*, the housing of a shaft lying transversely, driven by spiral gears at the same speed as the cam-shaft, and carrying at its other end (not shown) the spark timer; at *q*, the crank-shaft and crankpin; at *r*, the flange to which the flywheel is bolted; at *s*, the oil-pipe connections for supplying oil to the cylinders and main bearings; at *t*, the oil ring running on the crank-shaft and dipping into the oil well below, there being one of these rings at each main-shaft bearing; and at *u*, a ring that catches the oil fed by a mechanical oiler through the adjacent hole *s*, and leads it by means of the drilled hole *v* to the crankpin bearing.

The carbureter *w* takes air from a point near the cylinder, where it is warmed, and delivers it, by means of the L-shaped mixing pipe shown, to a cast connection at the top of the cylinder through which it passes, going through the throttle valve and then to both of the inlet valves. The throttle valve is usually of the butterfly type, and is provided for the purpose of controlling the power developed by the engine by regulating the quantity of vapor that enters the cylinders. The inlet valves are taken out by slackening the setscrews *x* and giving a quarter-turn to the yokes *y* that hold the setscrews *x*. As shown in the detail sketch in the upper right-hand corner of Fig. 14, the ends of the yokes *y* are slotted in opposite directions to receive the studs that hold them; a fraction of a turn releases them from the studs. Then the castings *z* can be lifted out, thus permitting the removal of the inlet valves and their cages, and of the exhaust valves after them.

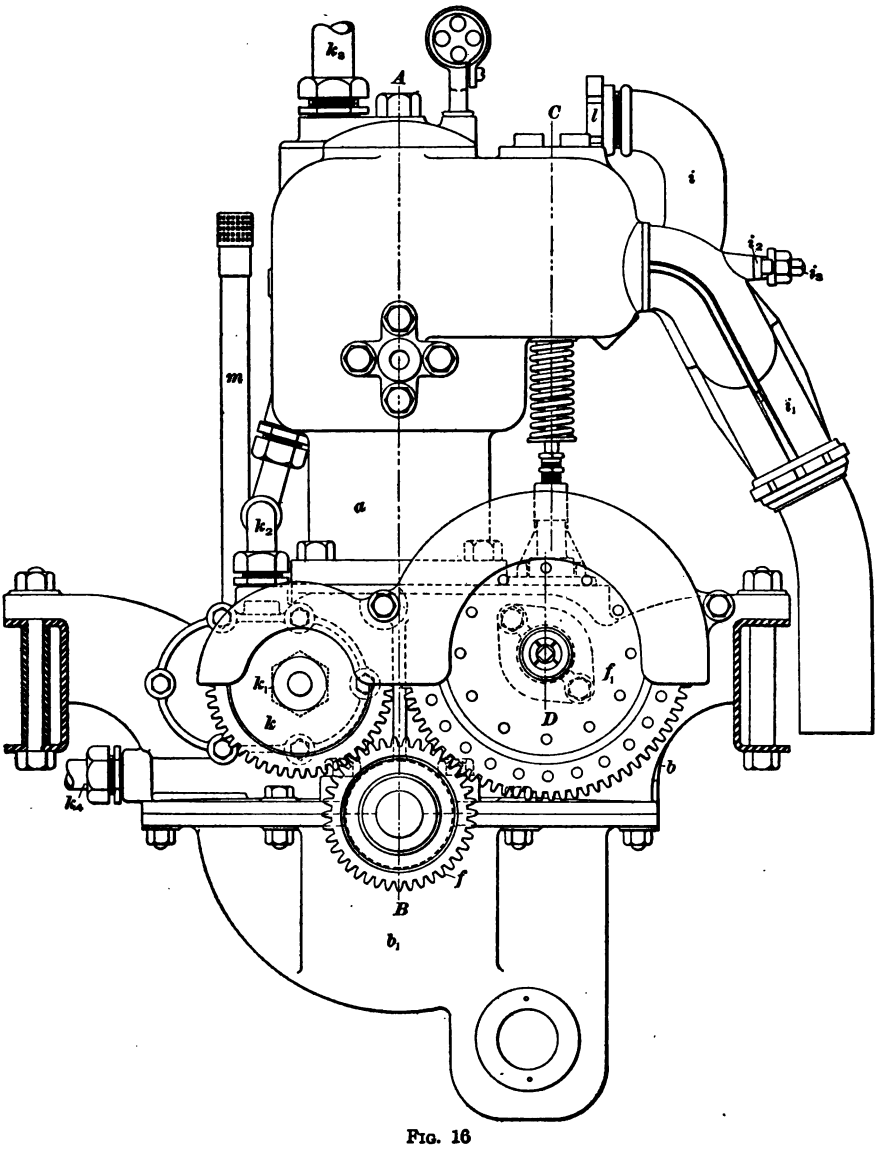


FIG. 16

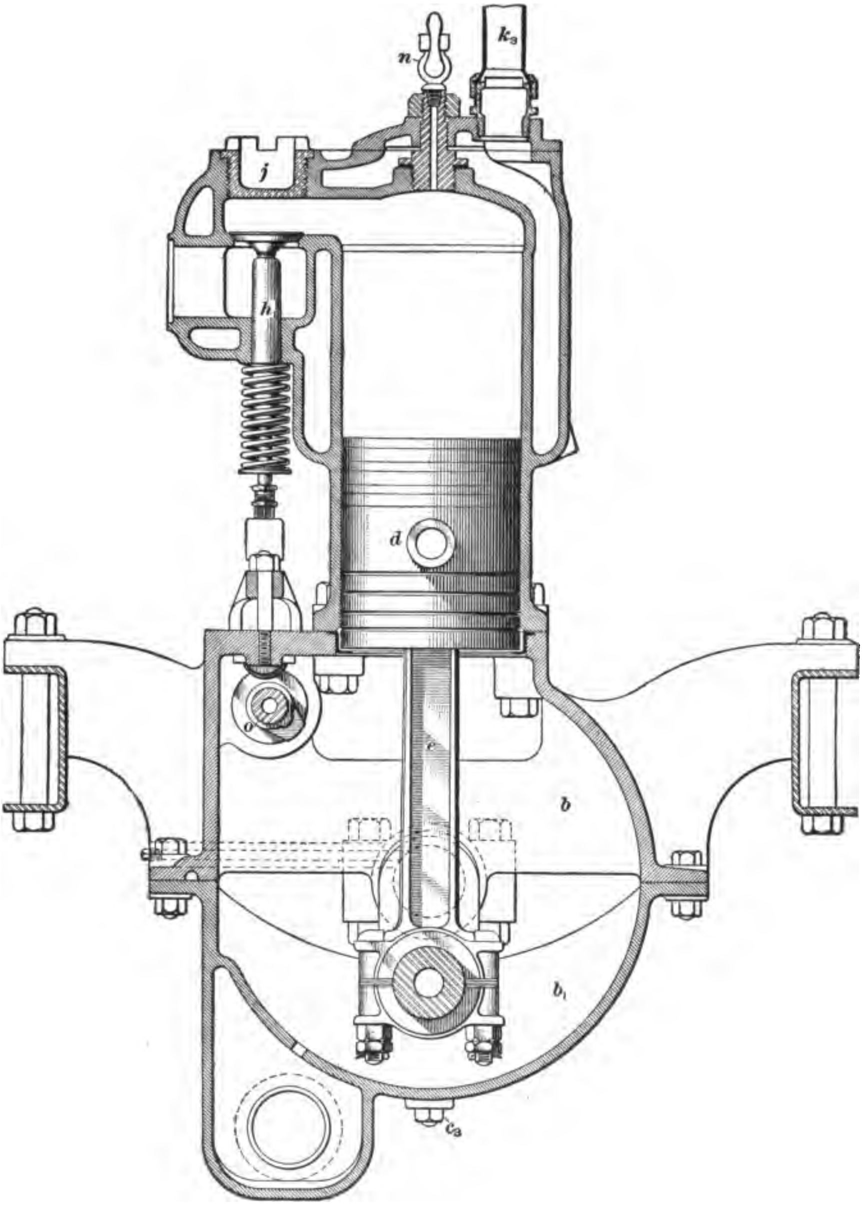
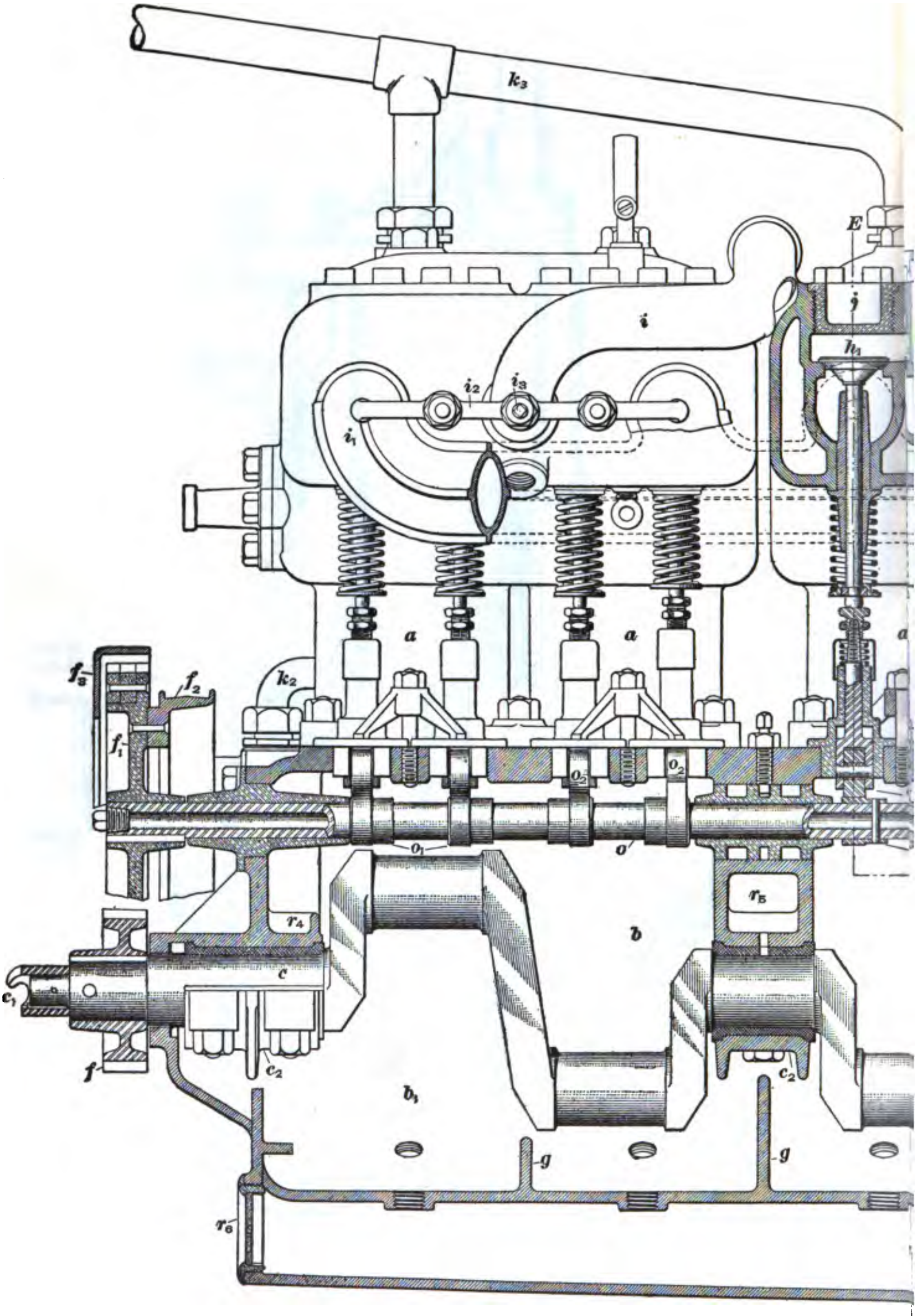
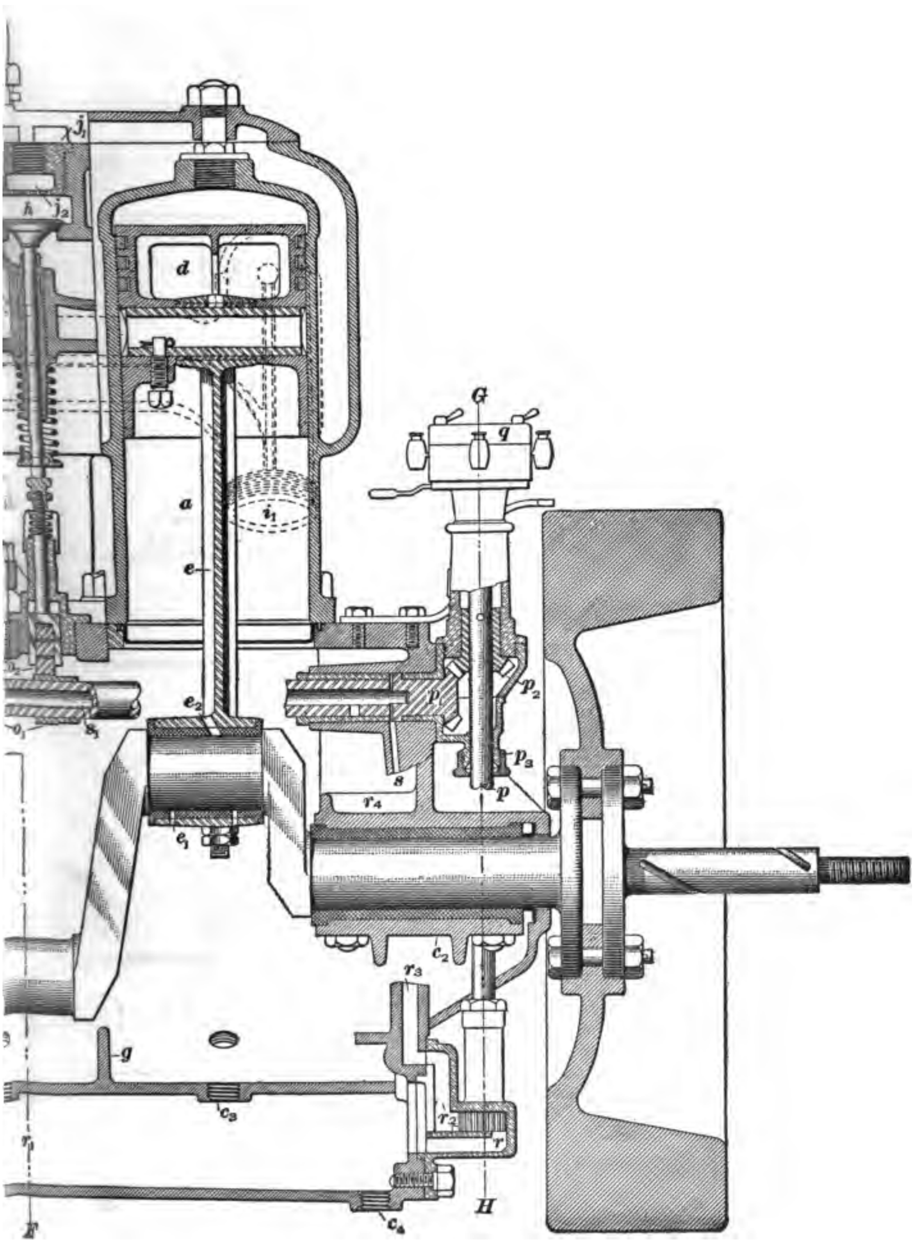


Fig. 18



k_3
E
j
h_1
i
i_2
i_3
i_1
a
a
a
f_3
f_2
f_1
k_2
o_2
o_2
o_1
o
r_5
r_4
b
c
c_1
f
c_2
c_2
b_1
g
g
r_6

FIG. 17



17

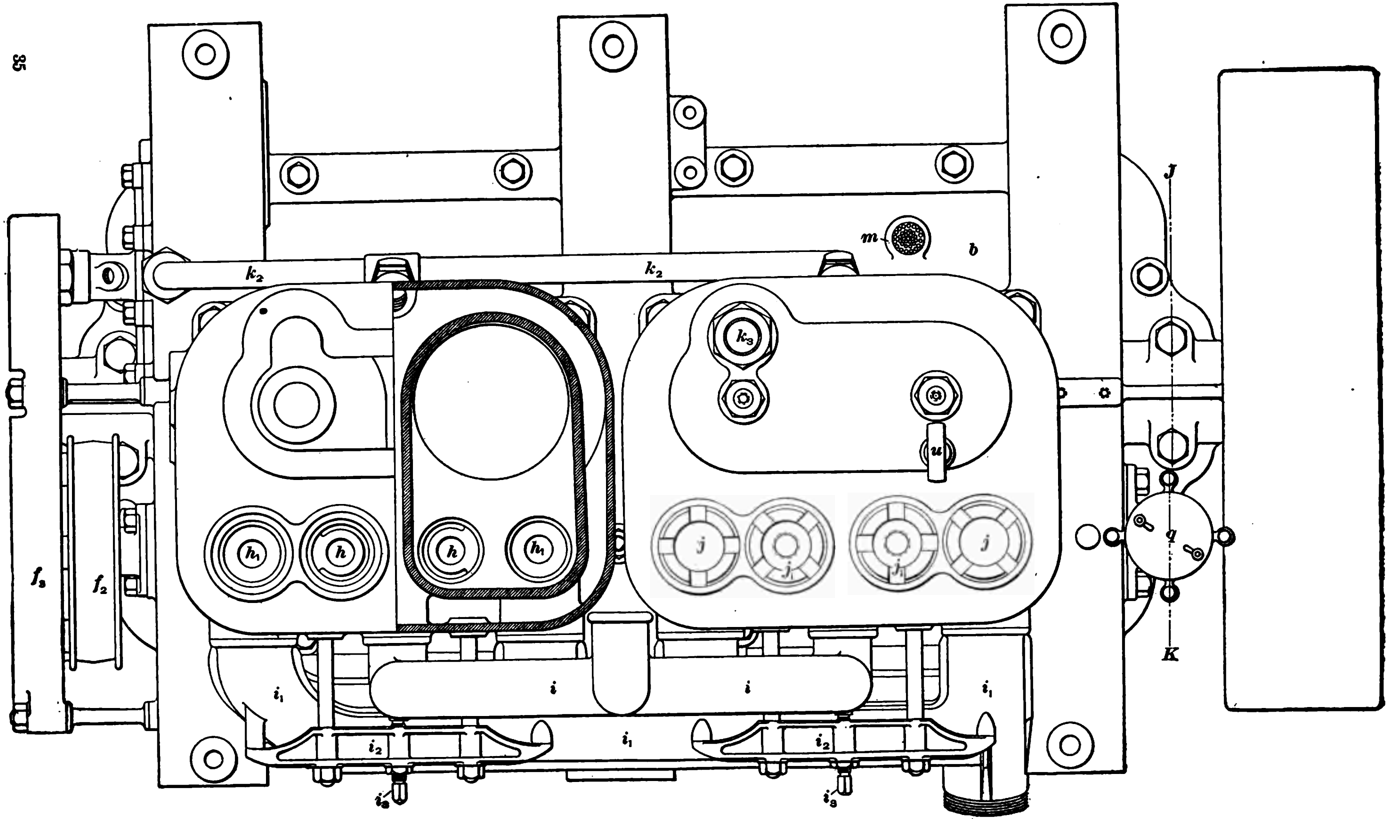


FIG. 19

MULTIPLE-CYLINDER TYPES

40. Automobile engines having more than two cylinders are usually of the vertical type. Figs. 16 to 19 show a four-cylinder four-cycle vertical water-cooled automobile engine having cylinders *a* of the twin type cast in pairs. Looking toward the flywheel end, the inlet- and exhaust-valve mechanism appears on the left-hand side of the engine, as indicated in Fig. 18. Of the accompanying illustrations, on all of which similar parts are indicated by similar reference letters, Fig. 16 is an end elevation of the engine looking toward the end opposite the flywheel. Fig. 17 is a longitudinal elevation partly in section, the cylinder *a* at the extreme right, together with the crank-case b, b_1 and crank-shaft bearings, being shown in a section taken on the center line $A B$ of Fig. 16, and the valve-operating mechanism being shown in a section taken on the line $C D$. Fig. 18 is a sectional elevation along the line $E F$ of Fig. 17, while Fig. 19 is a plan view, shown partly in section, looking down on the top of the engine. Fig. 20 is a sectional elevation of the timer and force-feed oil pump taken on the line $G H$ of Fig. 17.

Both the inlet and exhaust valves are located on the same side of the cylinders and are mechanically operated from a single cam-shaft. The inlet valves are placed adjacent to each other in each pair of cylinders and communicate with a common inlet port. Letters of reference applying to the principal parts of the engine are as follows: *a*, *a*, *a*, *a*, the four cylinders, one of which is shown in section in Figs. 17 and 18; b, b_1, the top and bottom halves of the crank-case; c, the crank-shaft; c_1, Fig. 17, a ratchet provided to engage the hand crank by means of which the engine is started; c_2, the bottom caps of the crank-shaft bearings, by which the shaft is supported from the top half of the crank-case, so that the lower half can be removed for inspection (shown in section in Fig. 17); *d*, the piston; *e*, the connecting-rod; f, f_1, the two-to-one pinion and gear, by means of which the cam-shaft is driven and the inlet and exhaust valves are operated; f_2, Fig. 17, the pulley for driving the fan that supplies a current

of air for cooling the water-jacket circulating water; f_3, Fig. 17, a housing over the gears f and f_1; g, g, g, partitions to prevent oil from flowing to one end of the crank-case while running up or down hill; h, h_1, the inlet and exhaust valves, respectively; i, the intake pipe, a plan view of which is shown in Fig. 19, which also shows part of the exhaust header, or manifold, i_1 and the yokes i_2 that hold the inlet and exhaust pipes in place (in Fig. 17, the exhaust header is represented by dotted lines in order that other parts might be shown); i_3, the setscrew for fastening the intake pipe; j, j_1, screw plugs in threaded openings through which the exhaust and inlet valves may be removed for cleaning or repairs; j_2, Fig. 17, the spark chamber in the plug j_1 over the inlet valve (the spark plug, which is not shown, is screwed into j_1, and the chamber j_2 communicates with the combustion chamber through small holes in the thin bottom of j_1, the holes permitting the fresh mixture to reach the spark plug on the compression stroke, and allowing the flame to strike through and ignite the charge, but preventing oil from reaching the spark plug); k, Fig. 16, the geared water-circulating pump; k_1, the stuffingbox of the pump; k_2, the water-pipe connection from the pump to the water-jackets, shown in plan in Fig. 19; k_3, the water connection from the top of the water-jackets to the radiator provided for cooling the circulating water; k_4, Fig. 16, the water connection from the cooling radiator to the pump; l, Fig. 16, the union for attaching the pipe from the carbureter (not shown) to the inlet header i; m (shown in elevation in Fig. 16 and in plan in Fig. 19), a crank-case vent pipe closed by a wire screen at its upper end and provided so as to permit oil to be poured into the crank-case and as a means of escape for the gases that leak past the pistons into the crank-case; n, Fig. 18, a compression relief cock; o, the cam-shaft carrying the cams o_1, Fig. 17, with which the push-rod rollers o_2 are always in contact; p, a shaft carrying the timer (a device by means of which the time of producing the spark in each of the cylinders is regulated); p_1, p_2, miter gears for driving the shaft p; p_3, Fig. 20, stuffingboxes; q, the spark timer; r, the rotary force-feed oil pump, the intake to which is protected by a wire

screen. The means for attaching the timer and the oil pump to the crank-case is shown in Figs. 19 and 20, the latter figure being a sectional view taken along the line *J K* of Fig. 19.

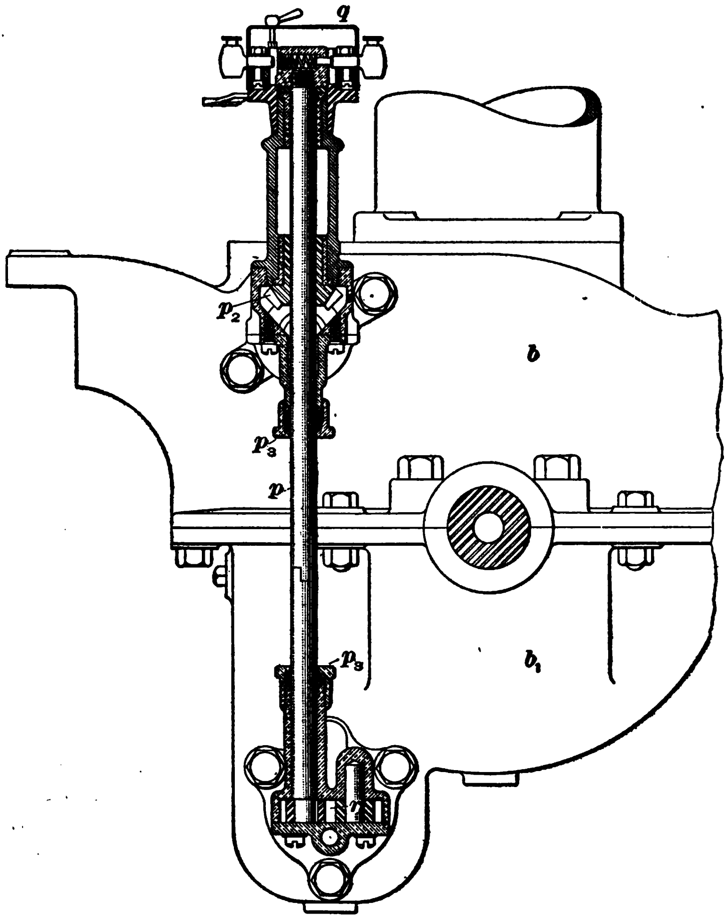


FIG. 20

41. The lubricating system of the engine just described is of the circulating type, in which the oil is pumped from the lower part of the crank-case and repeatedly applied to

the rubbing parts of the bearings. The oil pump r takes oil from the oil well r_1, Fig. 17, at the base of the crank-case and forces it upwards through the drilled passages r_2 and r_3 (partly broken away) to the large pockets r_4 and r_5 over the main bearings of the crank-shaft. A portion also goes up to the cam-shaft bearing s, where it passes, by way of suitable holes drilled in the shaft, to an oil passage s_1 running the entire length of the shaft. From this passage, it escapes to the three bearings by radial holes drilled in the shaft. The outer ends of the main bearings of the crank-shaft have oil retainers and return passages, by which oil working out to the ends of these bearings will return to the crank-case. A glass gauge r_6 affords a means of observing the height of the oil in the oil well. The crankpins are oiled through holes e_1 and e_2 drilled in the bottom caps and also in the top. Drainage plugs c_3 and c_4 permit the oil to be drawn off from the crank-case and also from the oil well.

FOUR-CYCLE AIR-COOLED ENGINES

SINGLE- AND DOUBLE-CYLINDER TYPES

42. Air-cooled four-cycle automobile engines of the single- and double-cylinder type, as well as those having more than two cylinders, are of the same general form of construction as engines of the water-cooled variety. As the volume of the air required for cooling is far greater than that of the water that would be employed for the same purpose, it is obvious that a correspondingly greater velocity of flow will be required for air than is necessary for water, and that the heat-radiating surface of the cylinder must be greatly increased by the use of projecting fins or ribs, pins, or other extended surfaces.

One method of increasing the heat-radiating surface of the cylinder of an air-cooled engine consists in thickly studding the surface of the cylinder with small pins $\frac{7}{32}$ inch in diameter, each projecting for a length of 2 inches. In order to add

considerably to their surface at small expense, the pins are threaded over their entire length, and then screwed into the cylinder walls to a depth of ⅛ inch. Each pin is calculated to have an exposed surface of 3.3 square inches, and as the average number of pins is nine per square inch of cylinder surface, the heat-radiating surface is multiplied nearly thirty times. The engine with which this method of cooling the cylinders is employed is hung horizontally lengthwise under the body of the automobile, and is placed somewhat low, so that it receives a good current of air whenever the motion of the vehicle is rapid. The effectiveness of the current is increased by small fans so placed as to blow directly on the cylinder heads. Although the pins are set together so closely that the velocity of the air stream through them must be somewhat low, this method of cooling is found effective.

43. A representative type of two-cylinder four-cycle air-cooled engine of the same general construction as the water-cooled engine described in Art. **38,** is shown in Fig. 21. In this figure, the cylinder is shown at *a*; cylinder head, at *b*; the piston, at *c*; the piston rings, at *d*; the piston pin, at *e*; the connecting-rod, at *f*; the inlet and exhaust valves, at *g*; the valve springs, at *h*; the bearing disks for valve springs, at *i*; the spark plug, at *j*; the relief cock, at *k*; the auxiliary exhaust outlet, at *l*; the valve rocker-arm, at *m*; the fulcrum bolt for the valve rocker-arm, at *n*; the rocker-arm yoke, at *o*; the valve-actuating push rod, at *p*; the push-rod guide, at *q*; the valve-operating cam, at *r*; the cam-shaft driving gear, at *s*; the timer cam, at *t*; the timer spring, at *u*; and the fiber block of the timer, at *v*. At *w* is shown the pinion on the crank-shaft *x* for driving cam-shaft gear *s*; at *y*, the crank-case cover; and at *z*, the flywheel. The valves, instead of being placed in the side of the cylinders, as in Fig. 13, are located in the cylinder heads, and both of them are mechanically operated.

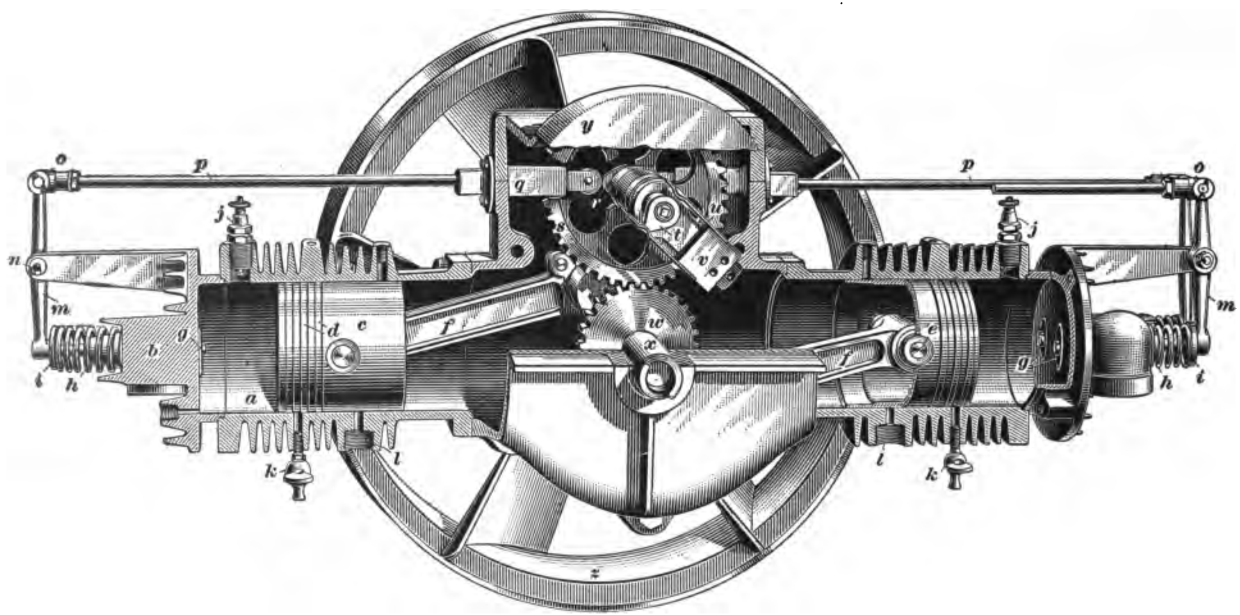


Fig. 21

FOUR-CYLINDER AIR-COOLED ENGINES

44. A popular type of four-cylinder vertical air-cooled engine, in which the heat-radiating surface is increased by the use of thin horizontal flanges cast on the cylinder, is shown in Fig. 22. The inlet and exhaust valves are mechanically operated, and open directly downwards into the cylinder heads, which are cooled by the same kind of horizontal flanges as the cylinder walls. The valves have short stems, and are actuated by rocker-arms and push rods, as shown.

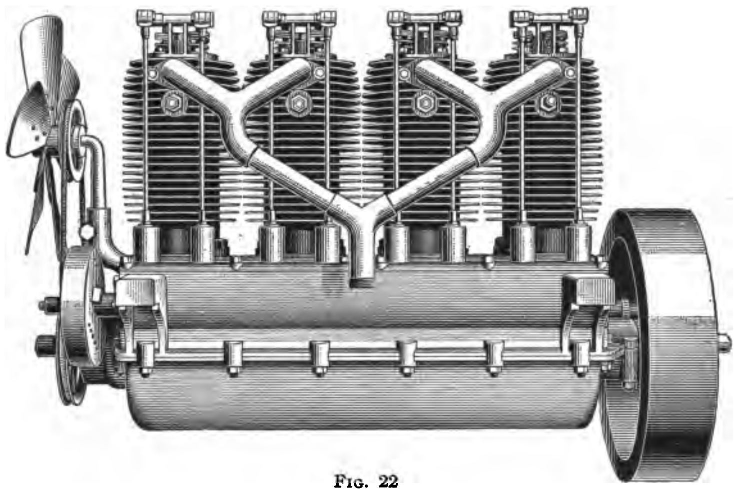


FIG. 22

The cylinders of such engines are always small, seldom having a bore that exceeds 4 inches. In order to prevent overheating in the combustion chamber, the compression is made somewhat low, especially when the bore is larger than 3½ inches. The engine illustrated is cooled by the large belt-driven fan at the front end.

45. Another form of the air-cooled type of four-cylinder engine is shown in Fig. 23. The inlet and main exhaust valves, which in later models are concentrically arranged, are located in the cylinder head and are mechanically operated in the usual way. The special feature that distinguishes

this engine from the ordinary air-cooled engine is an auxiliary cylinder exhaust controlled by the valve *a* and by the movement of the piston, which uncovers the port *b*

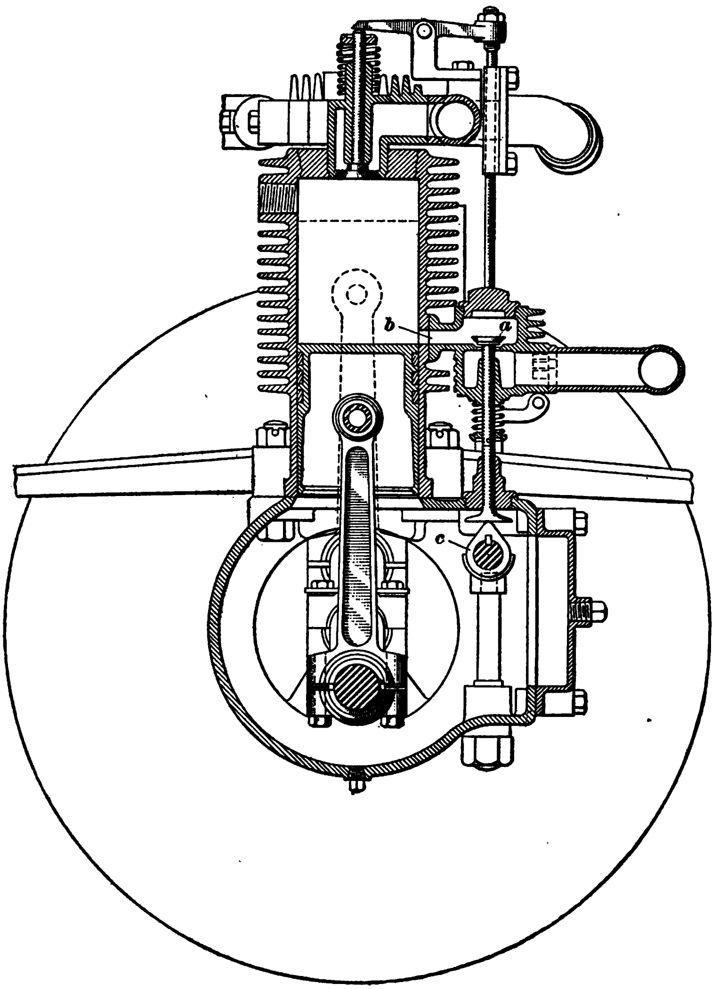


FIG. 23

near the end of the expansion, or working, stroke. The object of the valve *a* is to prevent the gases in the exhaust pipe from being drawn back through *b* on the suction stroke in

case the throttle should be partly closed. This valve is opened by the cam *c* just as, or before, the piston passes the upper edge of the auxiliary exhaust port, and closes when the piston has reached the end of its stroke.

The special advantage of the auxiliary cylinder exhaust for an air-cooled engine is that it gets rid of from two-thirds to three-quarters of the exhaust gas at a point remote from the cylinder head, where, of course, the highest temperatures are found. As the problem of cooling a cylinder by air is mainly to cool the hottest parts, that is, the cylinder head and the exhaust valve, the advantage of the arrangement shown is at once obvious. By insuring low temperatures at these critical points, it makes possible higher compression and higher engine speeds.

The regular exhaust valve in the combustion chamber port requires less force to open it when the auxiliary valve is used. This is due to the fact that the pressure of the burned gases in the cylinder is reduced to nearly that of the atmosphere after the auxiliary valve opens and before the regular exhaust valve is opened. The exhaust-valve mechanism is therefore subjected to less wear and can be of lighter construction than when no auxiliary exhaust is used.

MISCELLANEOUS TYPES OF AIR-COOLED ENGINES

46. Among a number of miscellaneous, unclassified, air-cooled automobile engines the following deserve notice: An air-cooled engine with four cylinders arranged in two pairs, the pairs being placed at 90° with each other around the crank-shaft, so that in what may be called the vertical type of this engine two of the cylinders are inclined on one side of the vertical at an angle of 45°, and the other two cylinders are inclined on the opposite side of the vertical at the same angle. When built with six cylinders, the latter are arranged in groups of three in the same manner.

Another engine is of the horizontal-opposed type with four cylinders arranged in pairs on opposite sides of the crank-shaft.

The distinguishing feature of the engine is that the pairs of cylinders are directly opposite each other, so that the bore of one of each pair is in line with the bore of its mate of the other pair. The pistons for the two cylinders are thus in line and form one integral piece so far as their movement is concerned. The portion lying between the ends of these twin pistons is cut out to pass around the crank-shaft and is otherwise suitably formed to carry a bearing that runs on the crankpin. The latter is completely surrounded circumferentially by the part that rigidly connects the two pistons.

Another form of air-cooled engine has several cylinders arranged radially in the same plane around a crank-shaft, the cylinders being spaced at equal angular distances apart. The distinguishing feature of this engine is that the cylinders rotate instead of the crank-shaft. The latter is held stationary and the cylinders rotate about it, acting as a flywheel to maintain the motion.

TWO-CYCLE AUTOMOBILE ENGINES

PRINCIPLES OF OPERATION

47. As indicated in Art. **11**, two-stroke cycle, or, briefly, two-cycle, engines are those which require two strokes of the piston, or one revolution of the crank-shaft, to complete the cycle. This is accomplished by eliminating the suction stroke and the exhaust stroke of the four-cycle type of engine.

Two-cycle engines of the type used on automobiles are known either as *two-port engines* or *three-port engines*, according to the number of ports opening into the bore of the cylinder.

The principle of operation of two-cycle engines will be understood by referring to Fig. 24, which shows various positions of the piston of a typical form of two-port two-cycle engine. At *p* is shown the piston; at *q*, the crank-shaft; at *a*, the crank; at *k*, the crankpin; at *r*, the connecting-rod; at *e*, the exhaust port; at *o*, the inlet, or transfer, port; at *b*, the transfer

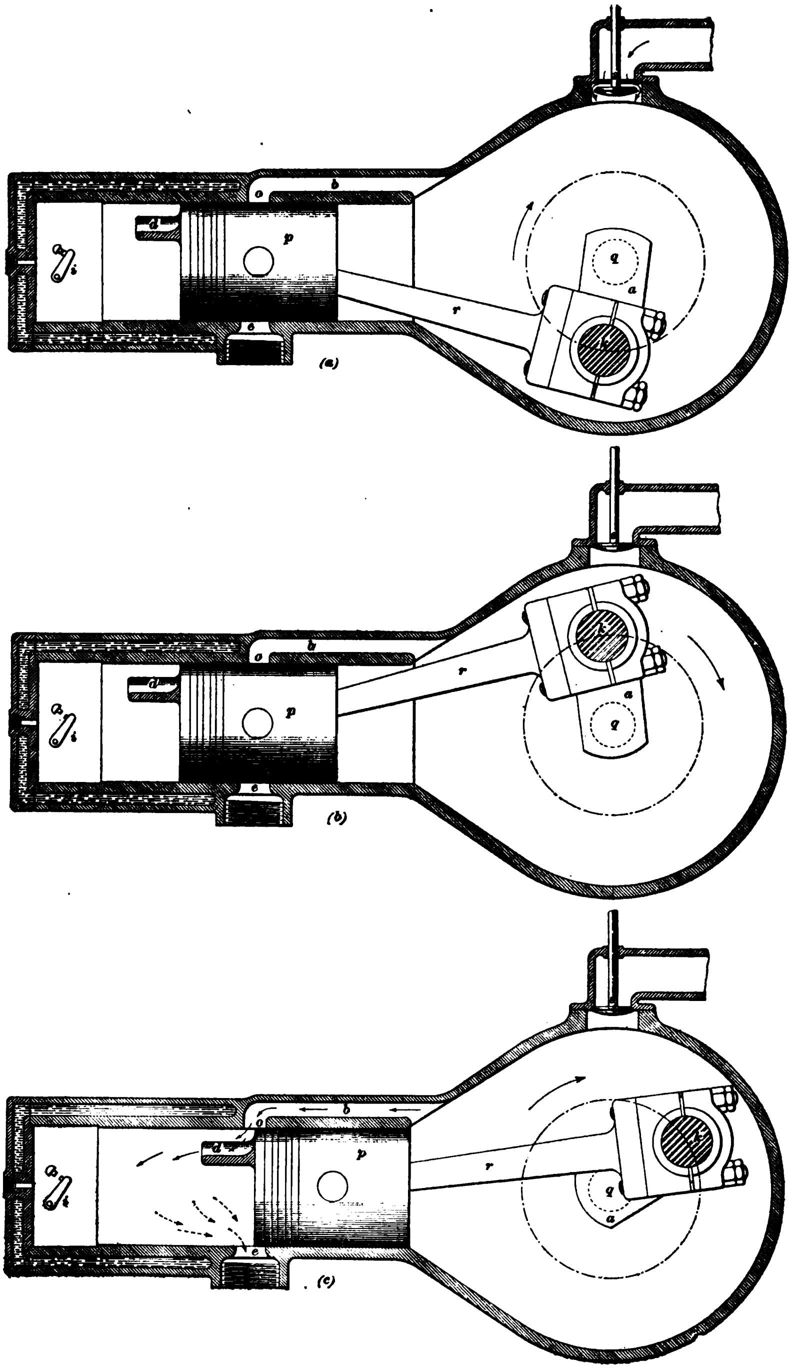


FIG. 24

passage, or by-pass, leading from the crank-chamber to the cylinder; at *s*, the inlet valve in the crank-case; at *d*, a deflector, or baffle plate, on the end of the piston; and at *i*, the igniting device at which the spark is produced.

48. In Fig. 24 (*a*), it may be assumed that the cylinder has been filled with the combustible charge that the piston is compressing during its inward stroke. At the same time, the partial vacuum created in the crank-case by the inward stroke of the piston draws more combustible mixture into the crank-case through the inlet valves. The compression in the cylinder and the drawing of combustible mixture into the crank-case continue until about the end of the inward stroke. The compressed charge is then ignited, and the increased pressure due to the combustion drives the piston out on its impulse stroke. The outward motion of the piston slightly precompresses the mixture in the crank-case, the inlet valve having been closed at about the end of the inward stroke of the piston. This stage of operation is illustrated in Fig. 24 (*b*).

As the piston approaches the completion of the impulse stroke, it begins to uncover the exhaust port *e*. As soon as this port begins to open, the burned gases in the cylinder begin to escape into the atmosphere. This escape is, or should be, rapid enough to allow the pressure in the cylinder to fall below that of the precompressed combustible mixture in the crank-case by the time the piston has moved out far enough to begin to uncover the transfer port *o*, through which a fresh charge then begins to enter the cylinder and to drive out the burned gases.

Fig. 24 (*c*) shows the piston expelling the burned gases and a fresh charge being taken into the cylinder. The baffle plate *d* deflects the incoming charge, so as to prevent it from flowing out with the burned gases. The more or less complete expulsion of the burned gases and the drawing of a fresh combustible charge into the cylinder are accomplished during the time the piston is moving through a small portion of the latter part of the outward stroke and early part of the inward stroke. The ports are then closed by the piston during the

early part of the inward stroke. The fresh charge is then compressed in the combustion chamber, and more combustible mixture is drawn into the crank-case.

A mechanically operated crank-case valve is used on some types of two-cycle automobile engines.

49. The series of operations taking place during the two-stroke cycle in the form of engine just described may be tabulated as follows:

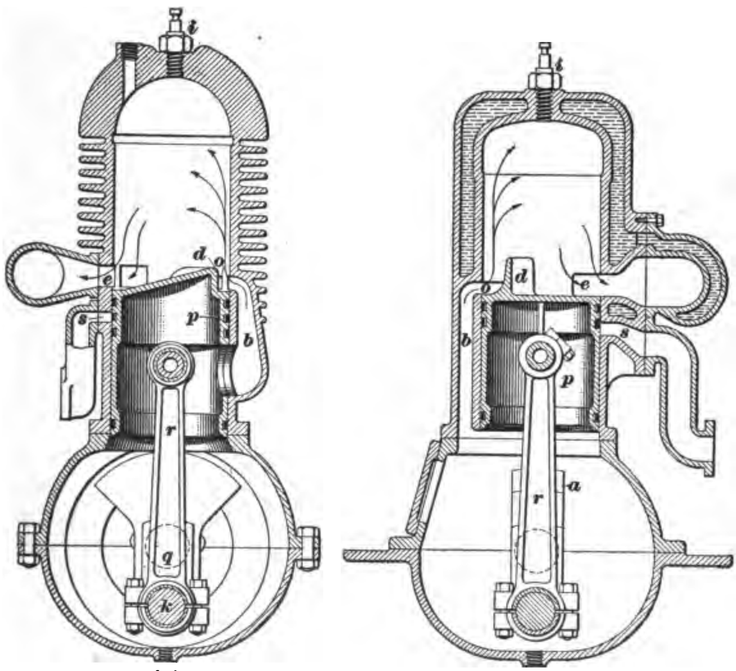
TWO-STROKE CYCLE

Cylinder	Crank-Case
First Stroke, Inward	
Compression; pressure rises; ignition near end of stroke, followed by explosion and rapid rise of pressure.	*Suction;* inlet valve open; pressure falls below atmosphere.
Second Stroke, Outward	
Expansion; pressure falls; exhaust followed by entrance of fresh mixture from crank-case.	*Compression;* pressure rises to from 4 to 8 pounds; charging cylinder; pressure falls to atmospheric pressure.

50. Valveless Two-Cycle Engine.—With the three-port type of two-cycle engine, instead of having an intake port that pierces the wall of the crank-case and is provided with a valve whose specific function is to close the port at the proper times, as in Fig. 24, the intake port pierces the wall of the cylinder at a point near the crank-case, and the use of a valve is thus obviated. Such an engine, air-cooled and water-cooled forms of which are shown in Fig. 25, is known as a **valveless two-cycle engine.** The same letters of reference as are applied to Fig. 24 are used in connection with Fig. 25.

In the valveless type of engine, the piston acts as a valve that mechanically opens and closes the intake port *s* through which the mixture is drawn into the crank-case for pre-compression. In the position of the parts shown, the piston has completed the power stroke and the incoming fresh

charge is helping to drive the products of combustion from the cylinder. While the piston moves from its farthest out-position to its farthest in-position, it produces a partial vacuum in the crank-case, until the crank-case intake port *s* begins to be uncovered. The mixture then flows into the crank-case through the port *s*; this flow is caused by atmospheric pressure. As the piston moves on its outward



(a) (b)

FIG. 25

stroke, the intake port *s* is first covered, and then precompression of the mixture in the crank-case takes place; this continues until the piston has moved out far enough to open the transfer port *o* so that the precompressed mixture can flow into the combustion cylinder. Aside from the method of drawing the mixture into the crank-case, the operation of the valveless engine is the same as that of the two-port two-

cycle engine with a valve in the port through which the mixture is drawn into the crank-case. The series of operations is the same as given in Art. **49.**

TYPICAL TWO-CYCLE AUTOMOBILE ENGINES

51. Two-Cylinder Engine.—A two-cycle valveless three-port two-cylinder vertical automobile engine having forced circulation of the cooling water is illustrated in Figs. 26,

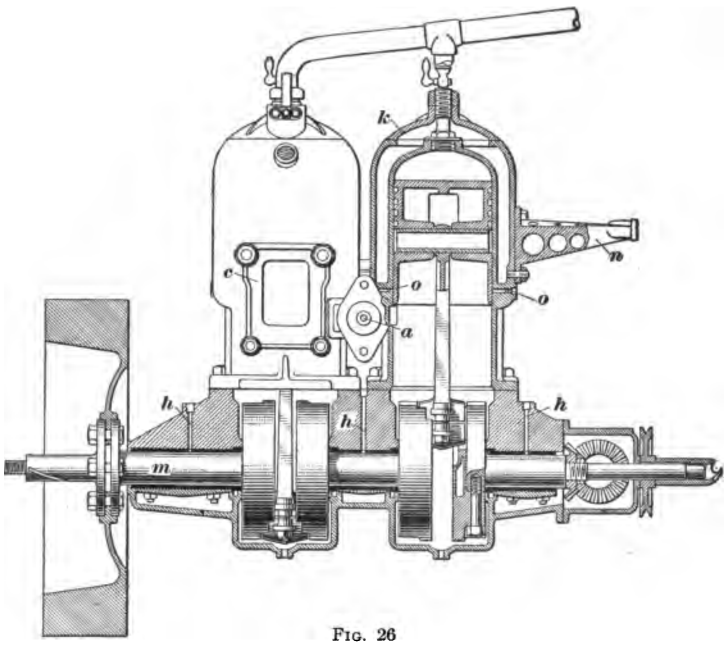


FIG. 26

27, and 28. In Fig. 26 is shown a sectional view of one cylinder and the crank-case, the section being taken on a plane that passes through the center lines of the cylinder and crank-shaft. The other cylinder is shown in full side view. Fig. 27 shows a sectional view on a plane that passes through the center line of one cylinder and is perpendicular to the length of the crank-shaft. Fig. 28 is mostly a full view from the top, but one cylinder is shown in horizontal section; the water

circulating pump is also shown in horizontal section on a plane through the center lines of the axis of its two gear-shafts. The cranks are at an angle of 180° with each other, so that the pistons move in opposite directions.

To the inlet opening *a* is attached the carbureter through which the mixture enters the cylinders below the pistons and passes into the crank-case through the port *b*, Fig. 27. This opening is formed in a triangular piece fitting in the angle between the two cylinders. On the inlet side of the cylinder is a pair of plates *c* and *d*, Figs. 27 and 28, forming the outside of the by-pass channel through which the mixture passes from the crank-case to the cylinders above the piston. As indicated in Fig. 27, *d* is a sloping plate that aids in directing the gases into the combustion chamber, the entire passage *e* through which the gases pass from the crank-case being visible. Fig. 28 shows the by-pass channel *e*, as well as the openings *b′* in the cylinder wall through which the gases pass into the cylinder; also, the bridge *f* separating these openings.

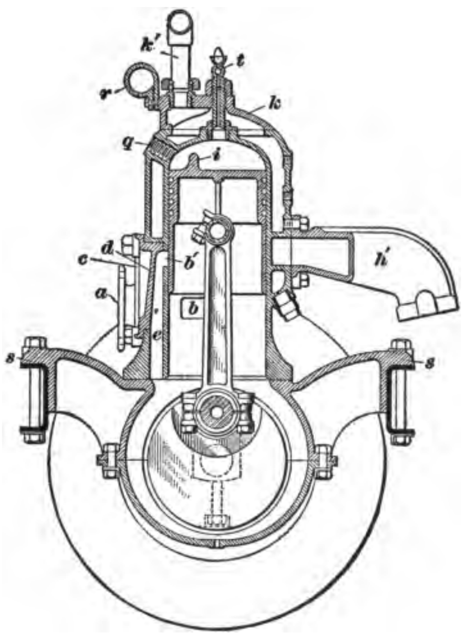


FIG. 27

At the exhaust side of the two cylinders, there are two oblong openings *g* in the sides of the cylinder, to which the exhaust pipes *h′*, Fig. 28, are secured. These ports *g* are separated by a central vertical bridge *g′*, and, as shown in the figure, the ports are larger in circumferential measurement

than the inlet ports, and their height is slightly greater. They are located at nearly the same distance from the top of the stroke as the inlet ports. The deflecting plate *i*, Fig. 27, on the top of the piston is carried close to the inlet side, in order that the inrushing mixture may be directed toward the cylinder head, and not allowed to cross the cylinder space and pass out through the exhaust port.

52. Circulation of the cooling water is maintained by a pump *j*, Fig. 28, at the left of the engine. The water enters each water-jacket immediately below the exhaust port, and leaves from the head-cap *k*, through the pipe *k'*, Fig. 27.

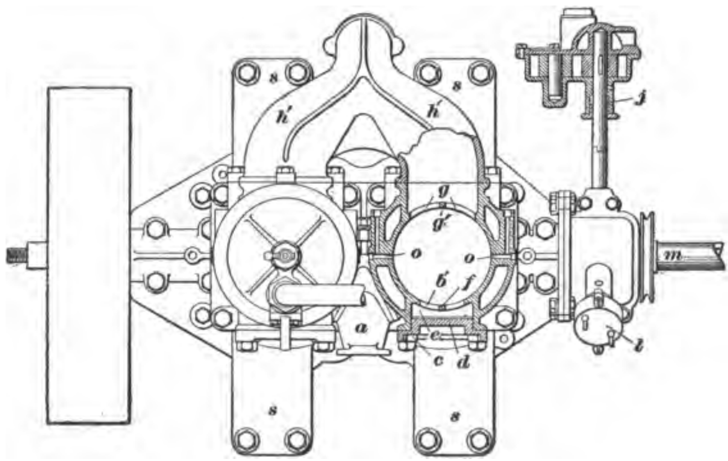


Fig. 28

The pump *j* and the spark timer *l*, Fig. 28, are driven from the crank-shaft *m*. The driving shaft for the pump *j* is horizontal, and that for the timer *l* extends obliquely upwards. Both of these shafts are driven by bevel gears in a casing at the forward end of the crank-shaft. Two of these gears are shown at the right-hand end of the sectional view in Fig. 26; the ones shown are those on the crank-shaft and the pump-driving gear. The pump and timer are in easily accessible positions. The bracket *n*, Fig. 26, is for supporting a rotary fan whose function is to create a circulation of air for cooling the radiator and engine.

53. Lubricating oil is fed into opposite sides of each cylinder through ducts *o*, Fig. 28. Connecting with these ducts are holes, or leads, from a force-feed lubricator. Similar leads *h*, Fig. 26, supply oil to the three bearings of the crank-shaft. The wristpins are clamped to the connecting-rods, giving them a bearing in both sides of the piston and facilitating lubrication, the oil flowing into the bearings from the cylinder walls. There is little room for an oil bath in the crank-case, but there is sufficient oil to maintain a splash that aids in lubricating the lower portions of the cylinder walls.

54. The spark plugs are screwed into the threaded openings *q*, Fig. 27, in the cylinder heads, giving them an angular position. A support *r* on the cylinder heads holds the electric wires led to the plugs. The main, or crank-shaft, bearings are arranged in the upper half of an aluminum crank-case supported by integral lateral arms *s*. The bottom of the case is made as small as possible, to reduce the crank-case capacity; it also serves as an oil reservoir. On each piston are four piston rings; the wristpins are hollow and are made of steel. The removable caps *k* on the cylinder heads allow a ready inspection of the water-jackets. The caps are held in place by hollow screws that carry priming cups *t*, the gasoline passages being through the screws.

55. Three-Cylinder Engine.—The three-cylinder vertical two-cycle engine shown in Fig. 29 has rotary valves *a*, one for each cylinder, mounted concentric with the crank-shaft *b*. The end of the crank-case *c* forms the valve seat. The valve is of the form commonly known as a *disk valve*, although more properly it is a flat ring. The valve for the extreme right-hand cylinder is shown in section in Fig. 29 (*a*) and in full side or end view in Fig. 29 (*b*).

The valve has lugs *d* that fit into holes in the crank-disk, or flywheel, *e*. The coiled compression spring *f* acts against each disk lug to press the valve against its seat, which is a part of one end of the crank-case *c*. In Fig. 29 (*b*) the port in the valve is shown at *g*, and the port in the crank-case at *h* by the dotted outline. The direction of rotation of the crank-

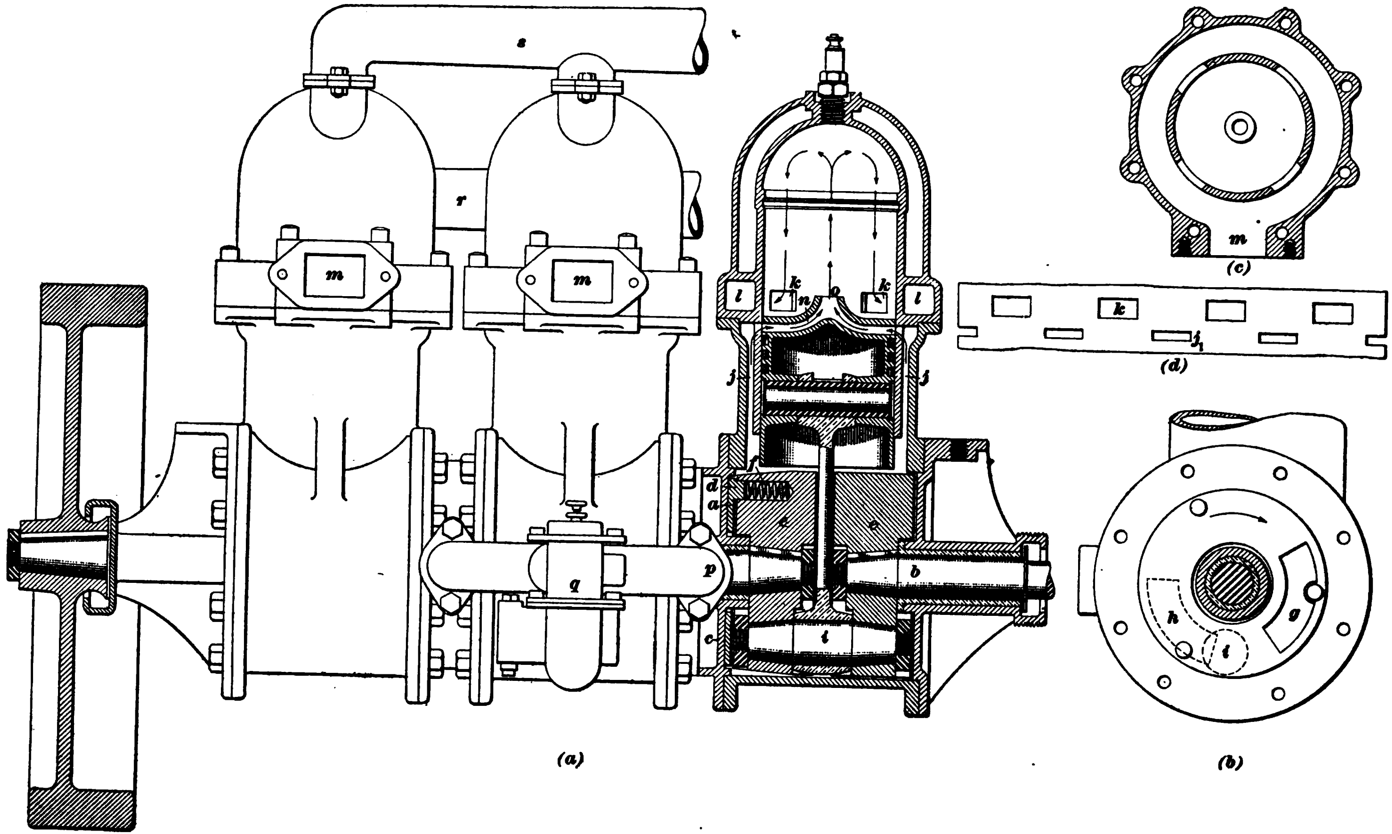


Fig. 29

shaft is indicated by the arrow. The cylinders of this engine are offset to one side of the crank-shaft as shown. The crankpin *i* is shown in its lowest position, in which position it is not directly below the crank-shaft but slightly to the left of it. It may be noted that the crank rotates through a considerable angle from the position shown before the valve begins to uncover the port *h*. The port is not closed until the crank has made something more than half a revolution

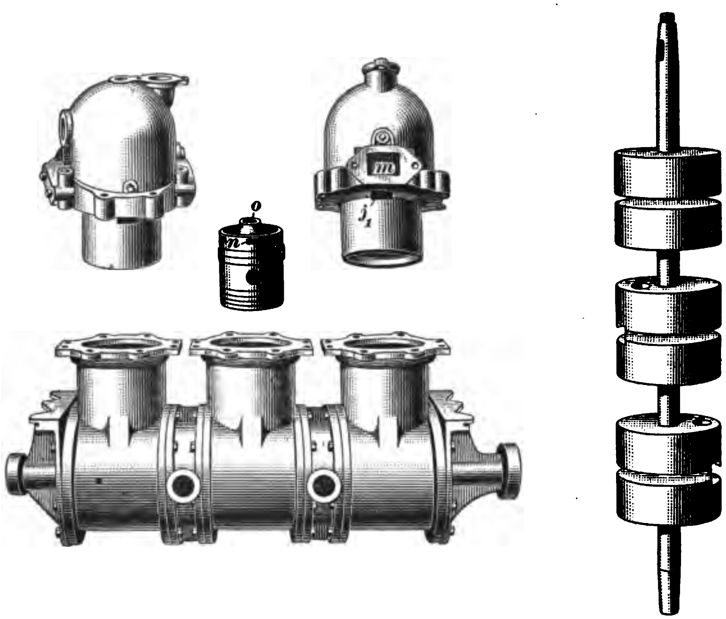


FIG. 30

from the position shown, which means that the crank-case port does not close until after the piston has started on its downward stroke.

As shown in Fig. 29 (*a*), there are four by-pass, or transfer, passages *j* from the crank-case to the cylinder. These passages open into the cylinder through four corresponding ports equally spaced circumferentially around the cylinder wall. There are also four exhaust ports *k* spaced in the same manner around the bore of the cylinder, all of which

lead into the annular passage *l* that completely surrounds the cylinder. A horizontal cross-section of the cylinder taken through the exhaust ports is shown in (*c*). The outlet from this annular passage to the exhaust pipe is at *m*.

56. The method of controlling the direction of flow of the incoming charge is unusual. The row of exhaust ports *k* is placed some distance above the inlet ports j_1, as indicated in Fig. 29 (*d*), which is a flattened out, or developed, view of part of the cylinder wall. The piston head has a partly

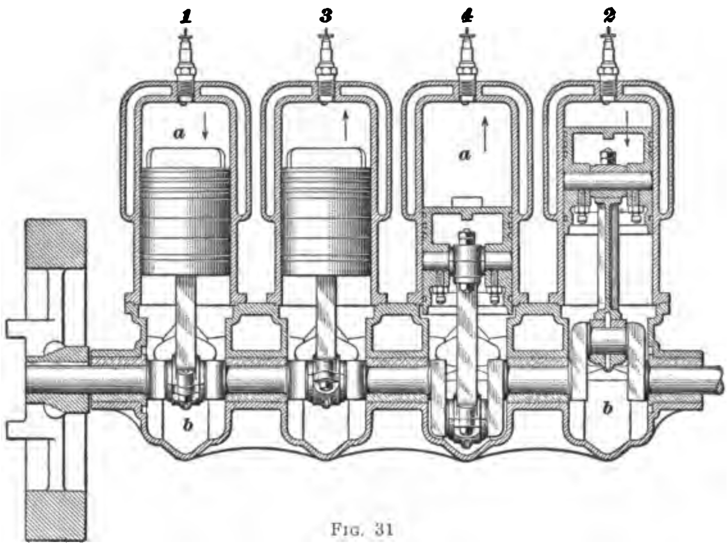


FIG. 31

hollow upper side, with ports *n* that register with the upper ends of the transfer passages when the piston is in its lower position. A charge then flows in through these piston passages and out at *o*, being directed upwards through the center of the combustion space as indicated by the arrows. The construction of the piston will be understood on referring to Fig. 30, which shows the principal parts of the engine separated from each other.

57. The combustible mixture is drawn into the crank-case through an opening at *p*, Fig. 29, in the casting located between

the crank-cases of the two cylinders and to which the crank-cases are fastened. This inlet branches into both crank-cases.

As shown, the carbureter *q* is placed in front of the middle crank-case, with branch pipes leading to the two parts intermediate between the crank-cases. The tapering inlet pipe *r* for cooling water is located near the middle of the upper part of the cylinders, and the hot-water outlet pipe *s* is at the extreme top.

58. Four-Cylinder Engine.—In Figs. 31 and 32 is shown a four-cylinder two-cycle engine of the three-port type. Each of the four cylinders *a* is cast separately, and is bolted to a one-piece crank-case *b* having for each crank a separate air-tight compartment, on both sides of which are handholes covered with aluminum plates bolted in place. Facing the flywheel, the crank-case inlet ports *c*, Fig. 32, are at the left side of the cylinders, and are connected to the carbureter by means of an inlet manifold having four throttle valves—one for each cylinder. The by-pass, or transfer, passages *d* through which the charge passes from the crank-case to the cylinders, are cast in the latter at the right and are covered by plates *e*. Fig. 32, which is not a cross-sectional drawing of the actual engine, is shown simply to illustrate in a general way the arrangement of the ports, which do not appear in the longitudinal section, Fig. 31. As indicated in Fig. 32, the exhaust gases are discharged through the ports *g* to a cast-iron manifold bolted to the left side of the cylinders. The engine

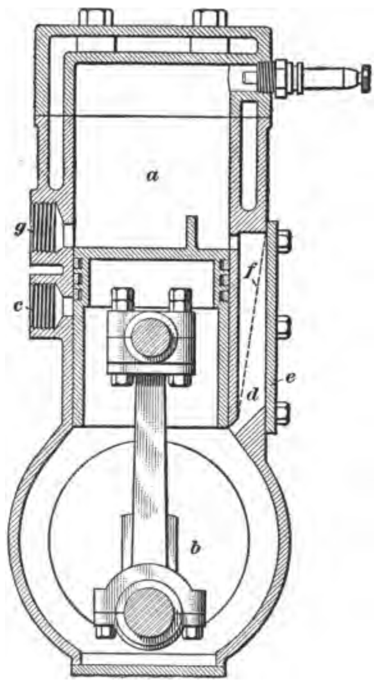


Fig. 32

is lubricated by means of a force-feed oiling device driven by belting from a secondary shaft provided for operating the timer and water-circulating pump. The spark plugs are located in the center of the cylinder heads, as shown.

The cranks are 90° apart, so that the pistons are brought to the tops of their cylinders in the consecutive order, *1–4–2–3*. The impulses occur in the same order that the pistons reach the tops of their cylinders. The cranks for cylinders *1* and *2* are 180° apart and stand perpendicular to those of cylinders *3* and *4*, which are also 180° apart with regard to each other. This arrangement of the cranks secures the best balancing of the moving parts in the cylinder and crank-case. The pistons in cylinders *1* and *2* move in opposite directions, and thus balance each other so as to prevent any great vibration. The same is true of the parts moving in cylinders *3* and *4*.

A wire-gauze screen *f*, Fig. 32, is placed obliquely in the by-pass between the crank-case and cylinder. The purpose of this screen is to prevent back-firing on account of the flame running down from the cylinder into the crank-case. The screen is composed of a very fine mesh of woven wire supported either by a stiff plate perforated with numerous large holes or by a coarse-wire screen with sufficient stiffness to hold the gauze in place. A flame will not follow a combustible mixture through a closely woven wire gauze. This is an application of the principle long ago put into use on lamps used in mines, the purpose of the gauze in this case being to prevent the ignition and explosion of inflammable mine gases.

GASOLINE AUTOMOBILE ENGINES
(PART 2)

DETAILS OF CONSTRUCTION

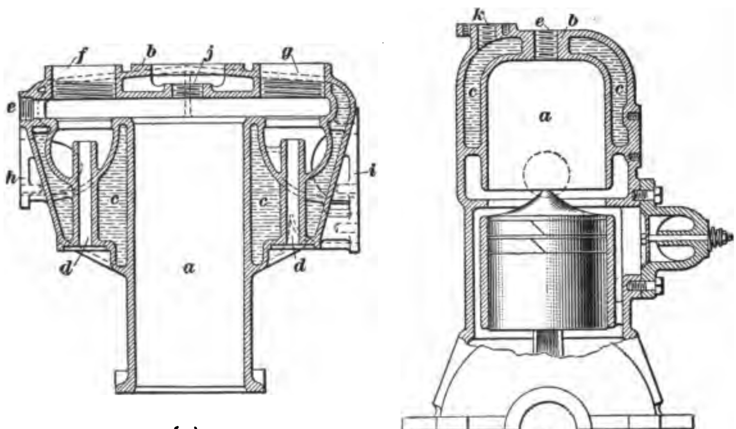
AUTOMOBILE-ENGINE CYLINDERS

WATER-JACKETED CYLINDERS

1. The descriptions of different constructions of leading types of automobile engines illustrated in *Gasoline Automobile Engines*, Part 1, deal with the engine parts in a general way, rather than with their details. In this Section, therefore, the construction of some of the most important of these parts will be explained, in order that the various forms in which devices for accomplishing similar purposes are made may be understood. Owing to the large number of designs, it is impossible to describe the details of the parts of all engines. However, a sufficient number of different constructions have been selected so that other forms in use will be understood without difficulty.

2. Cylinder, Head, and Jacket in One Casting.—A sectional view of a vertical gas engine of the four-cycle type, having the cylinder *a*, head *b*, and water-jacket *c* cast in one piece, is shown in Fig. 1 (*a*). Similar parts of a small two-cycle engine are shown in Fig. 1 (*b*). The object of casting the cylinder, head, and jacket in one piece is to avoid packing joints between the cylinder and head and between the cylinder and water-jacket.

Cylinders of the type shown in Fig. 1 (*a*) are usually provided with large water passages around the valve-stem guides *d*. The opening *e* is for the igniter, or spark plug; that on top, at *f*, is for giving access to and withdrawal of the inlet valve, and a corresponding one at *g*, on the opposite side, is provided for removing the exhaust valve. The intake pipe is connected to the flanged opening shown at *h* and the exhaust pipe to that shown at *i*, chambers being cored from these openings to the valves, as indicated by the dotted lines. At *j* is shown a compression-relief-cock opening, through which, when the cock is removed, scrapers may be inserted



(a) (b)

FIG. 1

for removing deposits of carbon from the top of the piston, and at *k*, Fig. 1 (*b*), is shown the outlet for the cooling water as it leaves the water-jacket.

3. Sometimes the inlet and exhaust valves are placed together on the same side of the cylinder, in which case both valves are operated mechanically by the same cam-shaft. A cylinder head of the latter form is sometimes cast with separate passages between the valve chambers and the combustion chamber, and the whole surrounded with the water-jacket.

Some four-cycle vertical engines are provided with auxiliary exhaust or relief ports that are opened at or near the end of

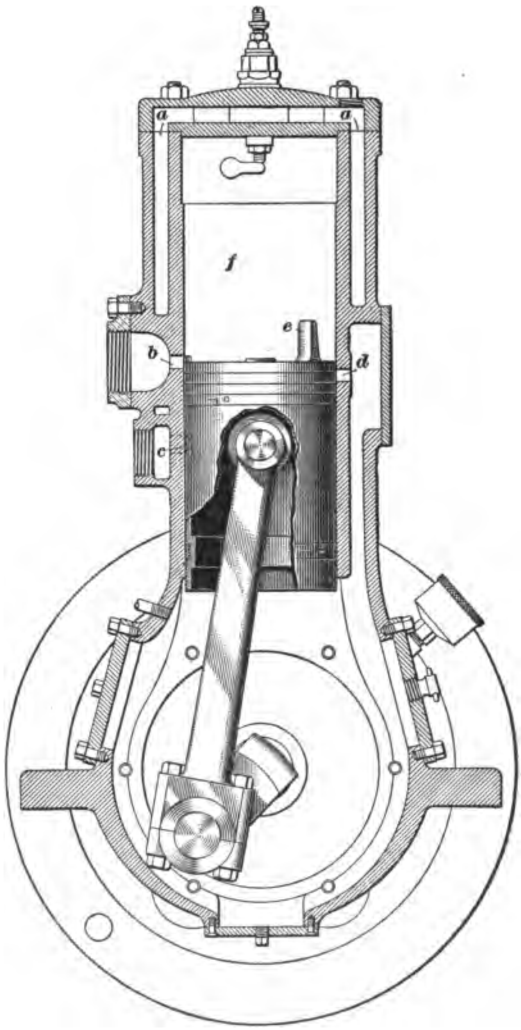


FIG. 2

the downward stroke. The purpose of the auxiliary port is to relieve the pressure on the exhaust valve, so that it will

open more easily. The pressure in a four-cycle cylinder at the time the exhaust valve is opened is frequently as high as 50 or 60 pounds, and the power required to lift the valve from its seat is therefore considerable. In one type of engine, a poppet valve is used in the auxiliary exhaust to prevent exhaust gases from passing through the port into the engine during the suction stroke when the engine is closely throttled.

4. Cylinder With Separate Head.—In a cylinder provided with a separate removable water-jacketed head, as shown in Fig. 2, the head end of the cylinder and the water-jacketed head contain passages, as shown at *a*, through which the cooling water circulates. The size of these openings in the cylinder is illustrated more clearly in Fig. 3, which shows an enlarged view of the top of the cylinder with the head removed, the water passages being shown at *a*. The openings in the head and in the head end of the cylinder must match when they are put together, and any gasket placed between them must have holes cut to match these openings. The bolt holes must be so located that the joint may be made tight.

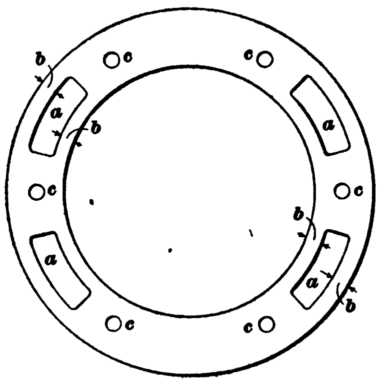


Fig. 3

Occasionally, the openings are made round, so that a part or all of them may readily be tapped and plugged. Since these passages should be as large as possible, the metal on the inside forming the cylinder wall and that on the outside is sometimes made as thin, in the case of small engines, as $\frac{1}{4}$ or $\frac{3}{8}$ inch. Under the high pressures developed in the gas-engine cylinder, the strips, shown at *b*, are so narrow that it is only with difficulty that the joint is made tight at these points. Cylinder heads for small engines are sometimes made so thin that they will spring between the studs shown at *c*, allowing the gasket, or packing, to be blown out by the pressure; this is due to

faulty design. Occasionally, the head and the cylinder are put together with a ground joint—that is, no packing or gasket is used between them—but such a joint is difficult to keep in good condition where the head must be removed for inspection or repairs. The difficulty of bringing the surfaces to such

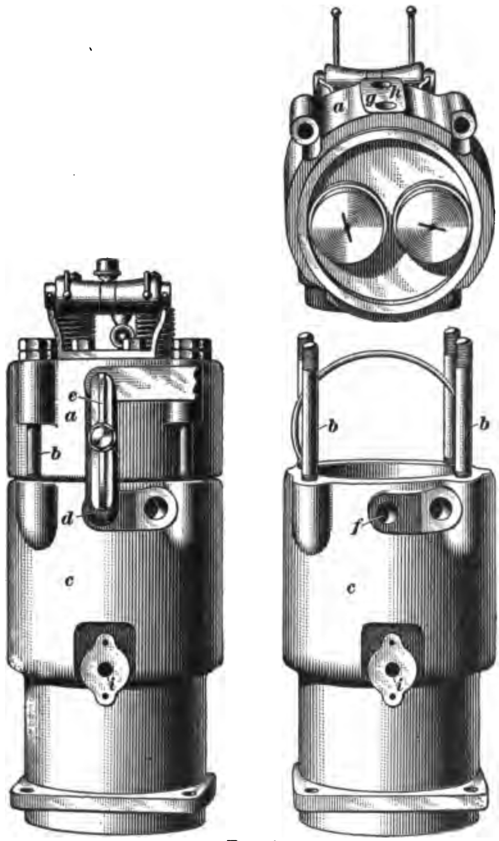


Fig. 4

a condition that they will not leak is so great after the head has been removed a few times that a gasket must be used.

5. Some manufacturers omit the cored openings for communication between the water-jacket and the head, using an outside connection instead, as shown in Fig. 4.

The detachable head *a* is held in place by four long stud bolts *b* that pass through lugs cast on the cylinder head, as shown. Communication between the head *a* and the water-jacket *c* of the cylinder is afforded by a separate detachable U-shaped hollow fitting *d* held in place by the yoke *e*, which also serves to hold in place the return-water manifold or pipe connection leading to the radiator. One end of the fitting *d* fits in the opening *f* leading to the cylinder water-jacket, and the other end fits in the hole *g* of the cylinder head. A horizontal division plate, which is cast in the head, divides the water space thereof into two parts. The circulating water from the cylinder jacket enters the lower space through the opening *g* and passes out into the return-water manifold through the opening *h*. Water from the supply manifold enters the jacket at *i*.

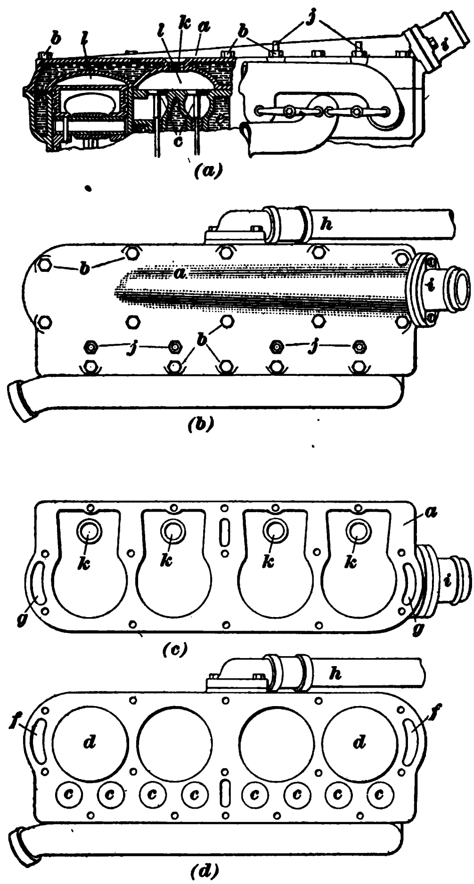


Fig. 5

On the bottom of the head there is a machined concentric tongue that fits into a corresponding machined groove in the upper end of the cylinder casting, and in the groove is placed a copper-asbestos gasket that serves to make a tight joint when the nuts on the stud bolts *b* are screwed down. The

manufacturers claim that, among other advantages of this construction, the machining of the whole bottom of the head contributes to the smooth running of multicylinder engines, because it insures combustion spaces of uniform capacity and lessens the liability to backfiring by eliminating the carbon-collecting projections, sharp points, rough edges, or uneven surfaces common to unmachined castings. Being located in the head, as shown, the inlet and exhaust valves that control the flow of the fresh charge and exhaust gases through passages cored in the head are surrounded by the circulating water and are thus kept cool.

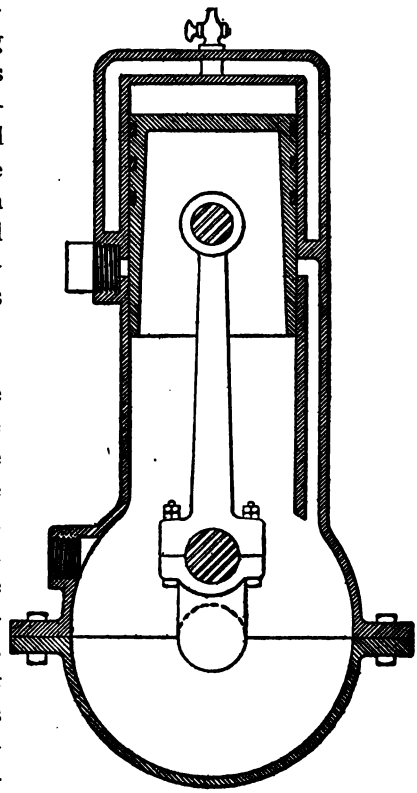


FIG. 6

6. The detachable head of another engine whose four cylinders are cast *en bloc*, that is, in one piece, is shown in sectional elevation and top and plan views in Fig. 5. When the head *a* is removed by unscrewing twelve capscrews *b*, the tops of the valves *c* and the tops of the pistons *d*, are exposed, thus facilitating the processes of removing deposits of carbon, regrinding the valves, and removing the pistons and connecting-rods. As shown by the sectional elevation, the valve stems are kept cool by the water circulating in the jacket *e*, from which the water passes into the head through two passages *f*, one at each end of the cylinder casting, corresponding passages *g* being formed in the head, as shown

by the bottom view of this part. The water that enters the water-jacket through the pipe *h* passes out to the radiator through the pipe *i* attached to the top of the head, as shown. The spark plugs *j* are screwed into the openings *k*, so as to project into the combustion chambers *l* formed in the head.

7. Ports in Two-Cycle Engine Cylinder.—The usual location of the ports in two-port two-cycle vertical engines having the inlet port on one side and the exhaust port on the opposite side is shown conventionally in Fig. 6. The lower edges of both ports are on a level and are even with the top of the piston when in its lowest position.

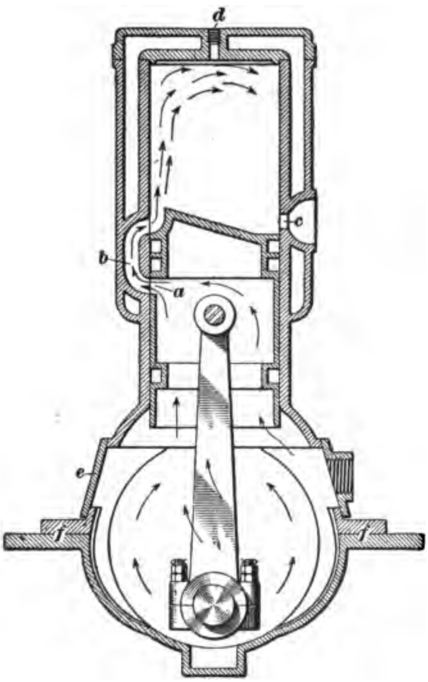


FIG. 7

Another type of two-port engine is shown in Fig. 7. In this case, a port *a* in the piston registers with the inlet port *b* leading to the cylinder, the object being to reduce the clearance in the crank-case and thereby increase the compression. The exhaust port is shown at *c*, and the spark-plug opening at *d*. Handhole plates at *e* give access to the crank-case, the lower half of which is bolted to the upper half at *f*.

8. The three-port type of two-cycle engine cylinder differs very little from the two-port type. The usual three-port arrangement is shown in Fig. 2. The exhaust port is shown at *b*, the gas-inlet port at *c* leading into the crank-case and the transfer port at *d* leading from the crank-case into the com-

bustion chamber *f*. In three-port engines, the crank-case inlet is usually placed directly below the exhaust, in order to utilize a part of the heat of the exhaust in heating the gasoline vapor as it enters the crank-case.

9. The ports opening into the cylinder bore of two-cycle engines of the types described are generally of one of the forms shown in Fig. 8. It will be seen that instead of using a single opening of considerable length circumferentially, several small openings arranged in a circumferential row are used. Such an arrangement is generally called a *bridged port* on account of the small bridge-like parts that divide into several small openings what might at first be assumed to be one long port. The row of openings thus formed is commonly referred to as a port, just as if there were no divisions. A port frequently occupies about half the circumference of the cylinder bore. In some of the more unusual designs, the bridged port extends completely around the cylinder bore. In such a case, the bridges are rather wide and are, of course, needed to hold the parts of the cylinder together; but even when the port extends only a short distance circumferentially, it is generally bridged in order to prevent the piston rings from springing into it and striking the edges of the rings against the edge of the port as the piston reciprocates. In some cases, to better prevent the striking of the piston rings against the edge of the port, the bridges are inclined, as at (*a*), instead of being made rectangular, as at (*b*).

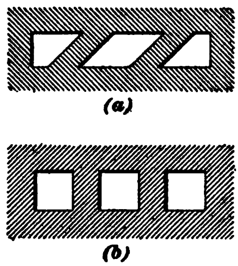


FIG. 8

WATER-JACKETS

10. The **water-jacket** that surrounds the cylinder of an automobile engine is necessary in order to prevent the damage to piston and cylinder that would otherwise result from burning the oil used for lubricating them. Great care

must be taken to select lubricating oils that will stand even as high temperatures as those reached in water-cooled cylinder walls. With such inflammable fuel as gasoline, it is necessary to keep the combustion chamber, the piston head, and the valves reasonably cool in order to avoid premature explosions due to hot cylinder walls. These walls are made hot by the high compression pressures commonly employed with the high-speed, or automobile, type of engine, as well as by the heat of combustion.

11. Water-jackets that are cast with the cylinder have the disadvantage that they cannot be readily cleaned when scale deposits accumulate in them. Hence, the water-jackets for

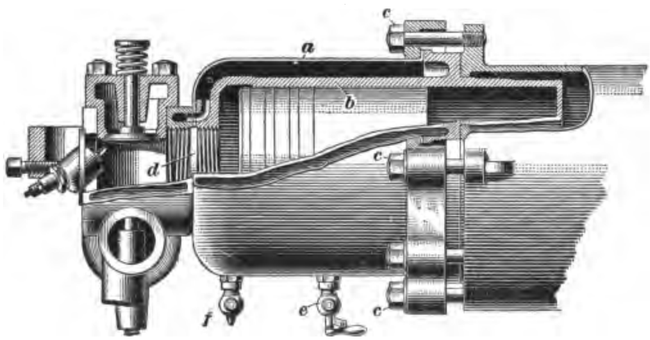


FIG. 9

some multicylinder vertical, as well as single-cylinder horizontal, engines are made of sheet metal, as shown in Fig. 9. The water-jacket, shown at *a* surrounding the cylinder *b*, is made of heavy sheet copper held in place, without gaskets, by means of the bolts *c* at one end and the right-and-left nipple *d* at the other end. A compression relief cock *e*, operated by means of a hand wheel on a rod extending outwards from the cock to a point outside the frame, is provided for reducing the compression pressure to facilitate starting. The water-jacket may be drained through a drain cock *f* screwed into a boss brazed to the outside of the jacket. Water-jackets of this type can be removed from the cylinder when it is necessary to clean them or to make repairs to the cylinder.

AIR-COOLED CYLINDERS

12. The internal construction of an **air-cooled cylinder** is the same as that of a water-cooled cylinder; also, the arrangement of the valves and other mechanism is similar. The external surface of an air-cooled cylinder, however, is extended, or increased, by various means, usually by the use of thin heat-radiating flanges, or ribs, cast integral with the cylinder walls. These ribs, or flanges, serve to conduct the

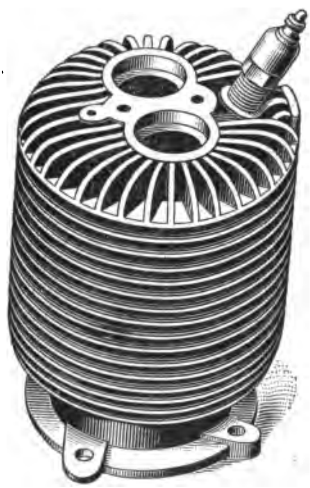


FIG. 10

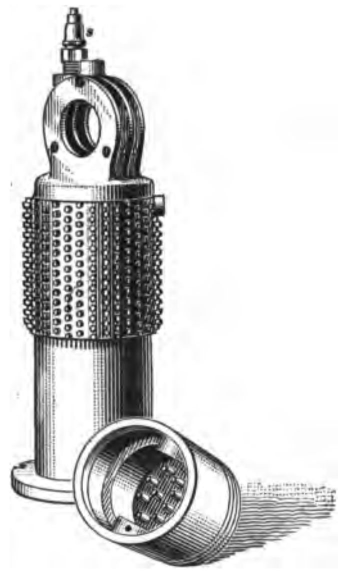


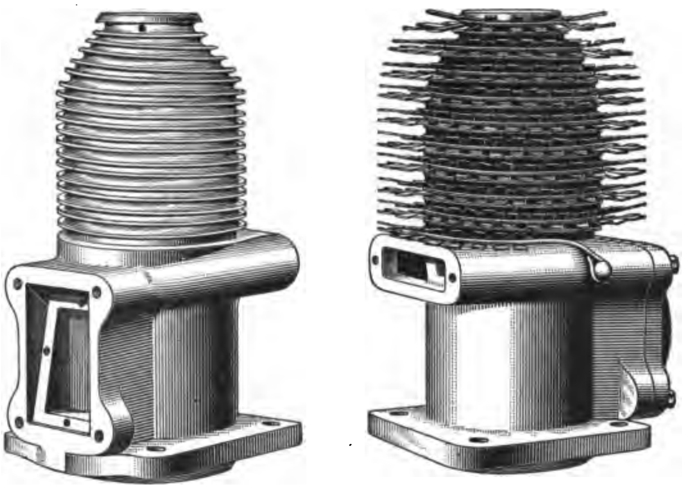
FIG. 11

heat from the cylinder walls, the heat being absorbed and carried away by the air that comes in contact with the flanges.

Fig. 10 shows a cylinder with cooling flanges that encircle the cylinder and are radially disposed on top. The parts surrounding the exhaust valve also generally have projections that aid in their cooling.

Fig. 11 shows a cylinder with pins or studs radiating from the outer surface of the casting. These studs, which are screwed into the cylinder wall, are sometimes threaded from end to end in order to provide a greater heat-radiating surface.

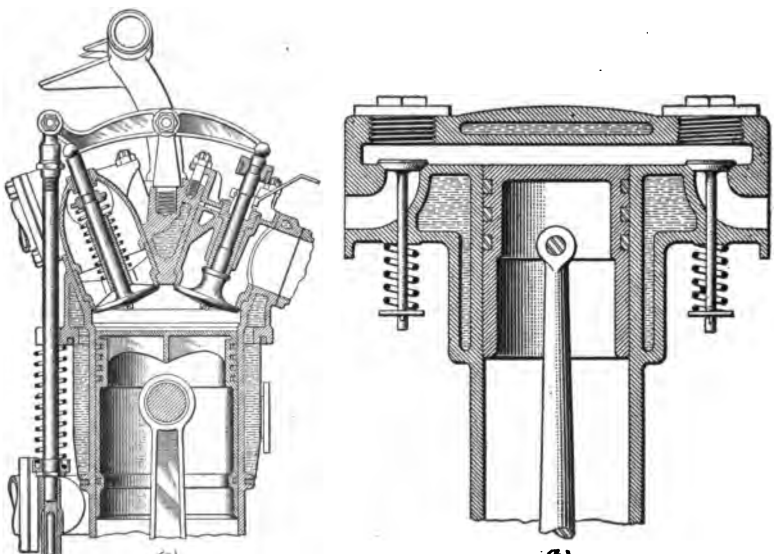
13. Plain and corrugated copper flanges have been brazed to cast-iron and steel cylinders to increase their heat-radiating surface, the copper carrying away the heat much faster because of its greater conductivity. Sometimes the flanges are forced on after machining the outside of the cylinder, but as copper expands more than the iron or steel of the cylinder when heated, the flanges tend to become loose, forming air gaps that prevent the conduction of heat. To obviate this difficulty, one manufacturer fastens copper spines to a two-cycle engine cylinder in the manner shown in Fig. 12.



(a) Fig. 12 (b)

The cylinder is finished inside and outside. On the outside the cylinder surface is deeply grooved. One of these spiral grooves is wider than the other and is intended to receive the copper spines. Both add much to the stiffness of the cylinder wall and, without making it heavy, insure its cylindrical form. At the head of the cylinder is a small hole into which the end of a steel wire is hooked, the other end being fastened as shown in Fig. 12 (*b*), which indicates how the cylinder appears after the spines are bound in place, the plain, unwrapped cylinder being shown in Fig. 12 (*a*). The copper spines are $\frac{5}{16}$ inch wide, $\frac{3}{64}$ inch thick, and about $2\frac{1}{2}$ inches long. They

are doubled at the middle to fit the groove into which they are forced and stand with both ends projecting. The steel wire is tightly drawn to bind them in place. When applied, this wire is heated, and as it cools it shrinks and grips the copper still tighter. It is also of such quality that it does not expand under heat as much as does the cylinder; therefore, the higher the temperature the tighter it binds. There is no tendency of the copper to expand away from the cylinder. The spines radiate like spokes of a wheel, and thus allow ample space for the air to circulate to the bottom of the grooves. The extra



(a) (b)

Fig. 13

groove in itself allows much additional surface to be reached by the air. The spines are more or less irregular, and thus offer a variety of paths to the air flowing around them. The two-cycle engine cylinder is well adapted to air cooling because the exhaust gases do not heat the head, but pass out at a point farthest from the head, which is also cooled from the inside by each new charge thrown against it. The head has no valve chambers or mechanism to prevent free access of air to the outside.

COMBUSTION CHAMBER

14. In Fig. 13 are shown two very different forms of **combustion chamber.** The one shown in Fig 13 (*a*) is made with as small a surface as possible for a given contained volume, the valves being placed in the cylinder head. The combustion chamber shown in Fig. 13 (*b*) represents the opposite extreme, the valves being carried out in long valve chambers on each side, and although the width of the valve chambers is less than the diameter of the cylinder, they add very considerably to the total wall area of the combustion chamber. Generally speaking, it is always desirable to reduce the size of the combustion space by having the valves as close to the cylinder as practicable.

CRANK-CASES

15. The moving parts of automobile engines are enclosed by a casing known as the **crank-case.** The upper part of this case serves as a frame, or bed, that supports the main, or crank-shaft, bearings and the cylinders, and the lower part serves as a receptacle for the oil used with the splash system of lubrication, which is commonly employed. The crank-case of the two-cycle type of engine is made air-tight in order that the gases may be compressed slightly before being admitted to the combustion chamber. With the four-cycle engine, an air-tight crank-case would not be advantageous, for when the hot gases leaked past the piston rings into the crank-case, there would be a tendency to overheat the bearings and burn the oil, and through imperfect lubrication rapid wear of the engine would result. To obviate these difficulties, the crank-cases of four-cycle engines are provided with one or more openings to which are attached pipes known as *breathers*.

16. A bottom view of the **five-bearing crank-case** of a four-cylinder four-cycle engine, that is, a view such as would be obtained by lying on one's back beneath the engine and looking upwards, is shown in Fig. 14, the lower half of the

crank-case, as well as the crank-shaft and connected parts, having been removed. A similar view of a **three-bearing crank-case,** but with the crank-shaft and connected parts in position, is shown in Fig. 15.

Referring to Fig. 14, it will be noticed that Babbitt-lined bearings are used, the brasses *a* containing Babbitt-metal linings *b* in which the journals rotate. The lower halves of the bearings are held in place by nuts screwed on the stud bolts *c* and held in position by cotter pins or locknuts. The lower halves of the crank-shaft bearings *a*, Fig. 15, are held in place by means of yokes *b* and cap-screws *c*, the latter being screwed into the crank-case, which is of iron. Movement of the brasses is prevented by pins *d* that extend through the yokes, these pins being secured, as shown, by means of cotter pins. The connecting-rod bearings *e* are similarly fastened.

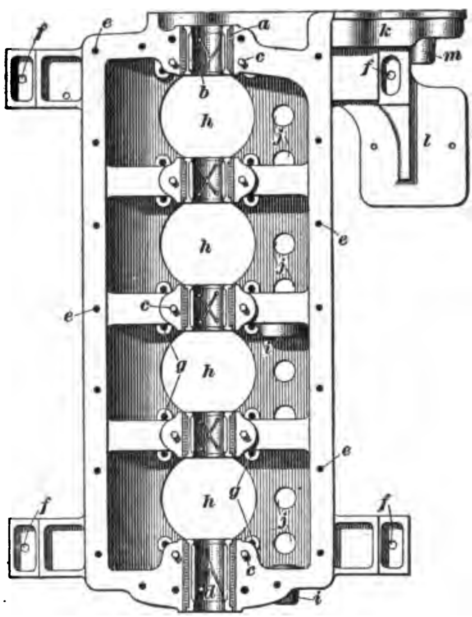


FIG. 14

Again referring to Fig. 14, it will be noticed that the bearing *d* at the flywheel end of the crank-case is made much larger than any of the others, because of the greater stresses it has to bear. The lower half of the crank-case, which is of aluminum, is attached to the upper half by means of bolts that pass through the holes *e*. The crank-case is generally fastened to sub-members of the frame of the automobile by means of bolts that pass through the holes *f*, while each of the cylinders is held rigidly in place by means of four capscrews that are

screwed into the threaded openings in the bosses *g*, the lower ends of the cylinders projecting through the openings *h*. The

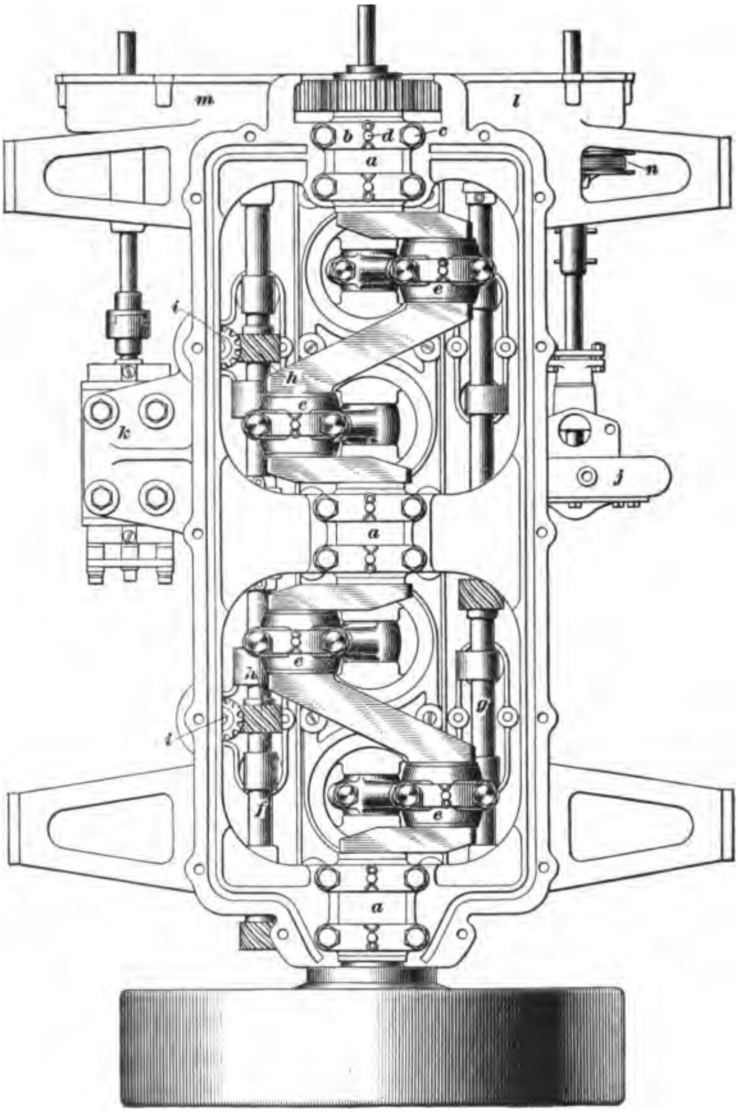


FIG. 15

lower ends of the inlet- and exhaust-valve push rods, operated by cams on a cam-shaft running in bearings *i* at each end and at the center of one side of the crank-case, project through guide bearings in the eight openings *j*. At *k* is shown the lower side of the housing around the gears by means of which the magneto bolted to the upper side of the bracket *l* is driven, the magneto driving shaft running in the bearing *m*.

17. On consulting Fig. 15, it will be seen that, instead of a single cam-shaft, as in Fig. 14, with all valves on one side,

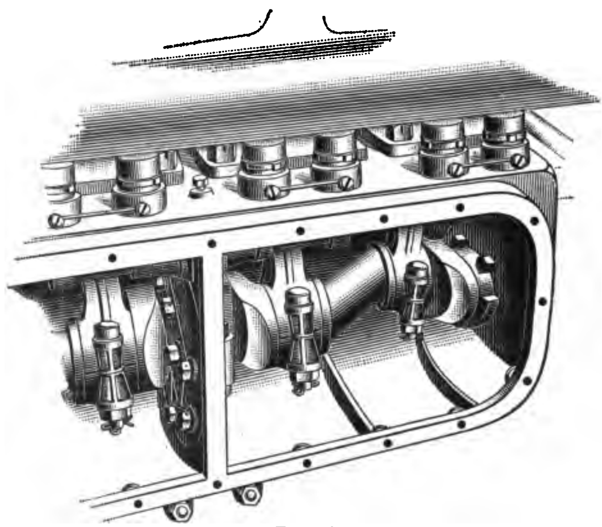


FIG. 16

there are two cam-shafts *f* and *g*, one at each side of the crank-shaft, the inlet and exhaust valves being located on opposite sides of the engine cylinder. The helical, or worm, gears *h* on the cam-shaft *f* mesh with driving pinions *i* attached to vertical shafts that carry the ignition mechanism. The gears that drive the pump *j* and the magneto mounted on the bracket *k* are housed in an extension of the crank-case at *l* and *m*, to which a cover-plate is attached by means of cap-screws. In the grooved wheel *n* on the pump driving shaft is a leather belt for driving the cooling fan. The lower halves of many crank-cases resemble a barrel cut in two lengthwise.

18. The crank-case is frequently provided with large, easily removable plates or panels in order that the parts enclosed may be inspected. On one or both sides of some crank-cases there are covered handholes through which the crankpin connections can be reached, as shown in Fig. 16. In others, the lower connections are reached by removing the lower half of the crank-case. When the base separates in line with the crank-shaft, the handhole plates are not absolutely necessary, although they furnish easy access to the crank-case to examine connections or to wash out dirty oil or grease.

19. Some two-cycle engines have the cylinder and crank-case cast in one piece, with separate end-plate bearings bolted to the crank-case to support the crank-shaft; others have their crank-cases parted in line with the center of the crank-shaft. Whatever method is adopted, it is necessary to have the center line of the cylinder exactly at right angles to the center line of the crank-shaft. Defective alinement is often found in engines having the cylinder and crank-case cast together, with end plates for crank-shaft bearings.

In multicylinder two-cycle engines, it is important that one crank-case should not leak into the other, otherwise there would be no crank-case compression. Such a condition is not unusual, and in a double-cylinder engine without removable cylinder heads it might be difficult to locate and overcome such troubles. With the heads removed, leakage can be readily detected by noting the way in which the gas or air enters the combustion chamber through the passover port, whether or not the compression in the crank-case is sufficient.

Occasionally, two-cycle engines are provided with stuffing-boxes on one or both ends of the crank-case bearings, and sometimes special forms of bushings are used with a fair degree of success to prevent leakage.

20. Crank-Case Breathers.—As shown in Fig. 17, **four-cycle crank-case breathers** are made up and attached in a variety of ways. In some cases they consist of plain pipe capped with wire gauze, as shown in (*a*), the pipe being screwed into a threaded opening in a boss thrown out

at some convenient place on the upper half of the crank-case. Sometimes the pipe is provided with a special cap, as shown in (*b*), and screwed into a threaded boss in one or more of the arms supporting the crank-case, with the interior of which the breather communicates, as shown in (*e*). Frequently, the breather, instead of being made up of pipe and fittings, as shown in (*a*), (*b*), (*d*), and (*e*), consists of a special one-piece

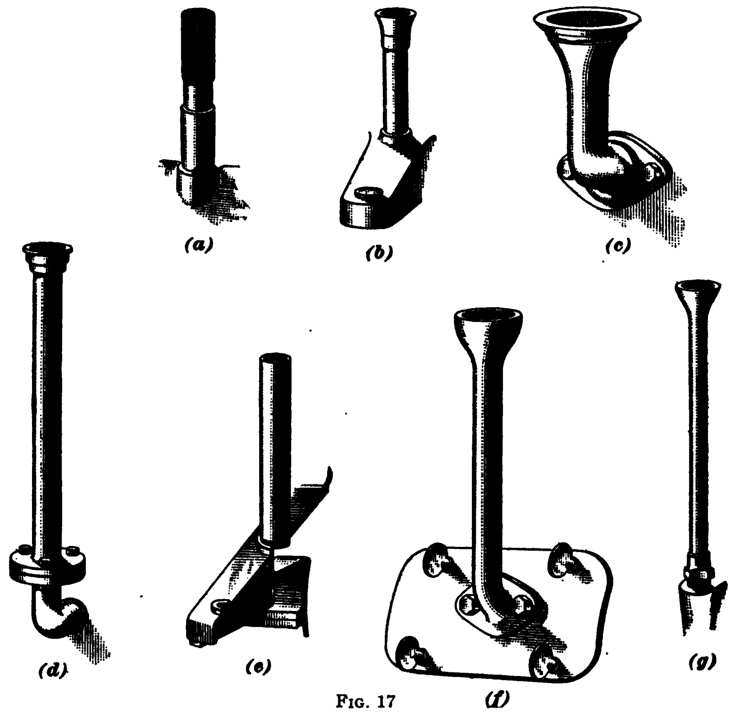


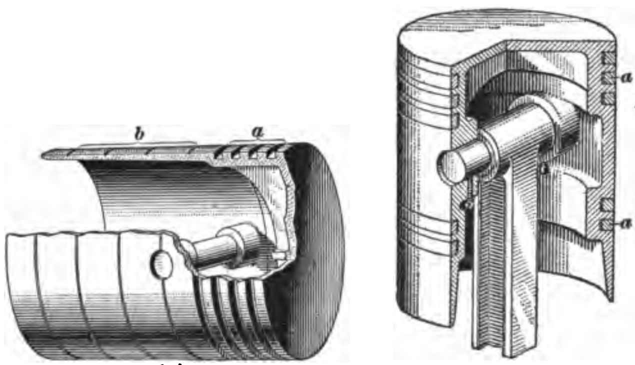
FIG. 17

casting with flanges, as shown in (*c*) and (*f*), and held in place by capscrews; or, one end of the casting or expanded pipe may be threaded, as in (*g*), and screwed into a special fitting made hexagonal at the base for screwing it into a larger threaded opening. One manufacturer uses a single breather pipe of the type shown in (*f*), attaching it, as indicated, to a handhole plate that covers an opening in one side of the upper half of the crank-case.

PISTONS

CONSTRUCTION OF PISTONS

21. The pistons of automobile engines are made hollow to receive one end of the connecting-rod, as shown in Fig. 18. Such pistons are of the so-called *trunk type*, being constructed in this way so as to obviate the use of a crosshead and guides and thus make possible a more compact engine. The piston consists of a hollow cylindrical iron casting carefully machined so as to have a good working fit in the cylinder. Near the head end of the piston there are three or more



(a) (b)

FIG. 18

grooves *a* in which are placed *piston rings* that serve to make an air-tight joint between the piston and the wall of the cylinder. The grooves *a* should be made of uniform width and square with the piston, so that the piston rings will not stick in the grooves when it is desired to remove them.

22. The smaller grooves *b*, Fig. 18 (*a*), aid in distributing the lubricating oil to all parts of the cylinder wall and in preventing loss of pressure due to blowing of the gases past the piston. They also help to carry oil to the piston pin, provided it is made hollow.

Some pistons have oil grooves of various shapes between the grooves *b* and the piston rings, and others, either with or without oil grooves, have one or two piston rings on the crank end of the piston, as shown in Fig. 18 (*b*). In some instances, the piston is made to taper slightly from the head to the crank end, to allow for more expansion at the hottest end. Pistons that fit too tightly are liable to become warped or distorted so that they stick in the cylinders and require considerable power to move them. In such cases, the power of the engine may be increased by slightly reducing the size of the piston.

23. The piston pin is usually set as near to the head end of the piston as possible, leaving just room enough for the piston rings beyond the piston pin. The object of thus locating the piston pin is to make the engine as short as possible, and, in the case of the two-cycle engine, to reduce the size of the crank-case so as to give a higher compression in the latter.

In two-cycle engines, the shape of the top of the piston is very important, particularly if the transfer port is located in the side of the cylinder. The part of the piston that projects upwards, as shown at *e*, Fig. 2, and that deflects the incoming charge of gas so that it clears the cylinder of the burned gases, is called a *deflector*, or *baffle*. Instead of using such a projection, the piston is in some cases so shaped as to deflect the gases in the same manner; such pistons are shown in Figs. 1 (*b*) and 7.

24. The piston of a two-cycle engine is made longer than the stroke, because otherwise the exhaust port would not remain completely covered during the compression stroke and the gas in the crank-case would escape to the atmosphere. The piston also covers the oil hole of the cylinder lubricator sufficiently to prevent the oil from being blown back through the oil passage and spattered on the sight-feed glass.

In order to have proper lubrication and to keep the exhaust port covered, except when exhausting, the piston is made

approximately 25 per cent. longer than the stroke of the engine. It is considered good practice to make the piston .001 inch smaller per inch of diameter than the cylinder. Thus, the piston for a 6-inch cylinder would have a diameter of 5.994 inches.

25. Some four-cylinder engines of the horizontal four-cycle double-opposed type are fitted with **double-headed pistons,** one form of which is shown in Fig. 19. At each end of the one-piece piston casting *a* is a head *b* like that of the ordinary type of engine piston. Each of the two double-headed pistons has a single connecting-rod *c*, so that instead of a four-throw crank-shaft, one having only two throws is used. Thus, for a four-cylinder engine of the opposed type, two connecting-rods and their bearings are eliminated. As a

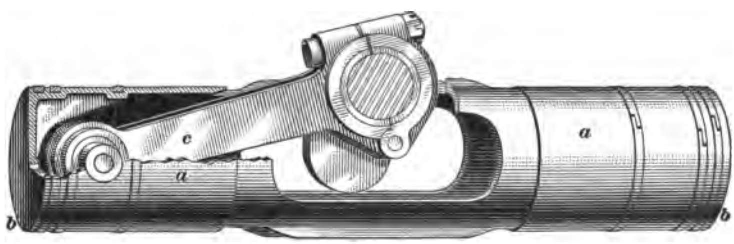


FIG 19

result of such an arrangement, the crank-shaft is shorter and stiffer than that of an opposed engine of the usual design.

The cylinders in which these double-headed pistons are used are cast in pairs, one-half of the crank-case being cast integrally with each pair and the two castings being bolted together on a plane passing through the center of the crank-shaft.

Pistons of the type shown in Fig. 19 are sometimes made with two concentric heads of equal area at each end, working in corresponding opposed concentric cylinders, connection to the piston castings being made as shown. One manufacturer uses double-headed pistons having an automatic inlet valve at the center of each head, a special type of ball-bearing connection to the crank-shaft being substituted for the connecting-rod.

PISTON RINGS

26. On account of the mechanical impossibility of making a solid piston so that it will have an air-tight and at the same time a free-running fit in the cylinder under the conditions met in automobile practice, elastic, expansible **piston rings** usually of close-grained, gray cast iron, are used to make a tight joint. For this purpose the piston is grooved as shown at *a*, Fig. 18, and rings of the form shown in Fig. 20 are sprung, or snapped, into the grooves. These rings are commonly called *snap rings*. They are split, or cut, in two on one side so that they may have an expansive elastic action to press them closely against the cylinder walls. Piston rings are made of such diameter that they press lightly against the wall throughout their entire circumference. The joints in the ring where it is split are made in several different forms, some of which are illustrated in Fig. 20.

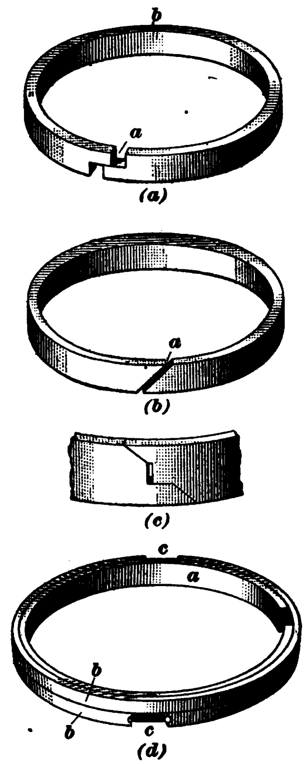


FIG. 20

When there is only one ring in each groove, there are usually three or more rings on the piston. With some engines, however, only two grooves are cut in each piston, in which case two rings are placed side by side in each groove.

The small circumferential grooves that are sometimes made in the piston between its open end and the piston rings, as shown at *b*, Fig. 18, serve the double purpose of distributing the lubricating oil and of aiding in making an air-tight joint.

27. In Fig. 18 (*b*), an additional pair of piston rings is shown near the open, or crank, end of the piston. The rings

placed in this position are generally called *oil rings*. They are supposed to aid in distributing the lubricating oil over the surface of the cylinder bore, and also to regulate the amount of oil that passes up from the crank-case into the combustion chamber. In order to accomplish this regulation, they are made in different forms to meet the condition under which the engine operates with regard to the amount of lubricant that is splashed, or thrown, into the open end of the cylinder. In some cases, they are made with true cylindrical surfaces, in the same manner as the other rings. In other cases, the outer surface of the ring is beveled part way across the surface and the ring put in place with the beveled side either toward the open end of the piston or away from this end, according to whether the desire is to have the ring allow more or less oil to pass by it than in the case of a ring with a true cylindrical outer surface. The oil rings also aid in making an air-tight joint.

28. The piston ring shown in Fig. 20 (*a*) is of uniform cross-section, with the ends lapped at the parting, as shown at *a*. There should be more spring in the ends of the ring than at the back *b*; consequently, the ring is frequently made eccentric, as shown in Fig. 20 (*b*). The parting in this case is a diagonal split, as shown at *a*, while the parting shown in Fig. 20 (*c*) is a combination of the other two. The diagonal parting is less likely to cut or scratch the cylinder than the others, as no portion of its parting line is parallel with the motion of the piston. One manufacturer uses three composite rings of the type shown in Fig. 20 (*d*) besides a plain wristpin ring on each piston. The composite rings consist of a heavy, plain, wide ring *a* on the outside of which are two thin rings *b* broken at *c* on opposite sides and pinned, as shown, quartering the break in the inner ring. The office of the heavy inner ring *a* is to produce the expansive force, while the thin outer rings conform perfectly to the shape of the cylinder.

CONNECTING-RODS AND CRANK-SHAFTS

29. A common type of automobile-engine **connecting-rod** is shown in Fig. 21 (*a*). It is of I-shaped section, the large end *a* being split at right angles to the rod through the center of the bearing and having a brass lining *b*. The two parts of the bearing are held together by the bolts *c* and *d*, which pass through the cap *e*. The bolts are provided with locknuts to prevent the nuts from loosening.

The smaller, or piston-pin, end *f* is forged solid, then bored out, and a brass bushing pressed into place, as shown at *g*. The piston-pin end shown in Fig. 21 (*b*) is split in the manner shown, a heavy capscrew being used to draw the parts tightly

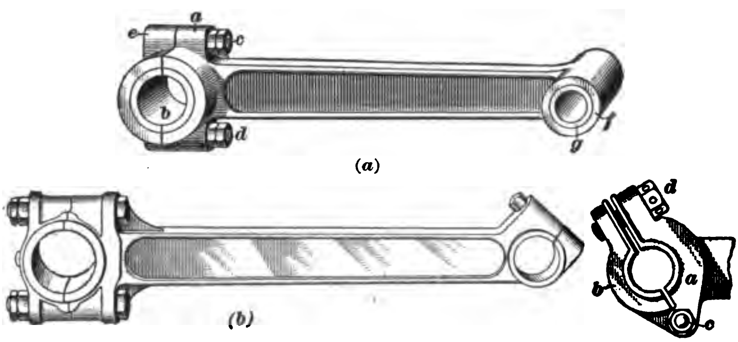


FIG. 21 (c)

against the piston pin, which turns in bearings in the piston casting.

Fig. 21 (*c*) shows a hinged crank-pin end sometimes used on connecting-rods for automobile engines. The end *a* and cap *b* are hinged at *c*, and a screw *d* is provided to hold the parts together. When the piston end of a connecting-rod is made solid and bored out, it is frequently provided with a bronze bushing. In the more expensive engines, the piston pin and the bushing are often made of case-hardened steel, and both pin and bushing are ground to fit.

30. **Crank-shafts** for automobile engines are made of special grades or alloys of steel, so that they may be as light

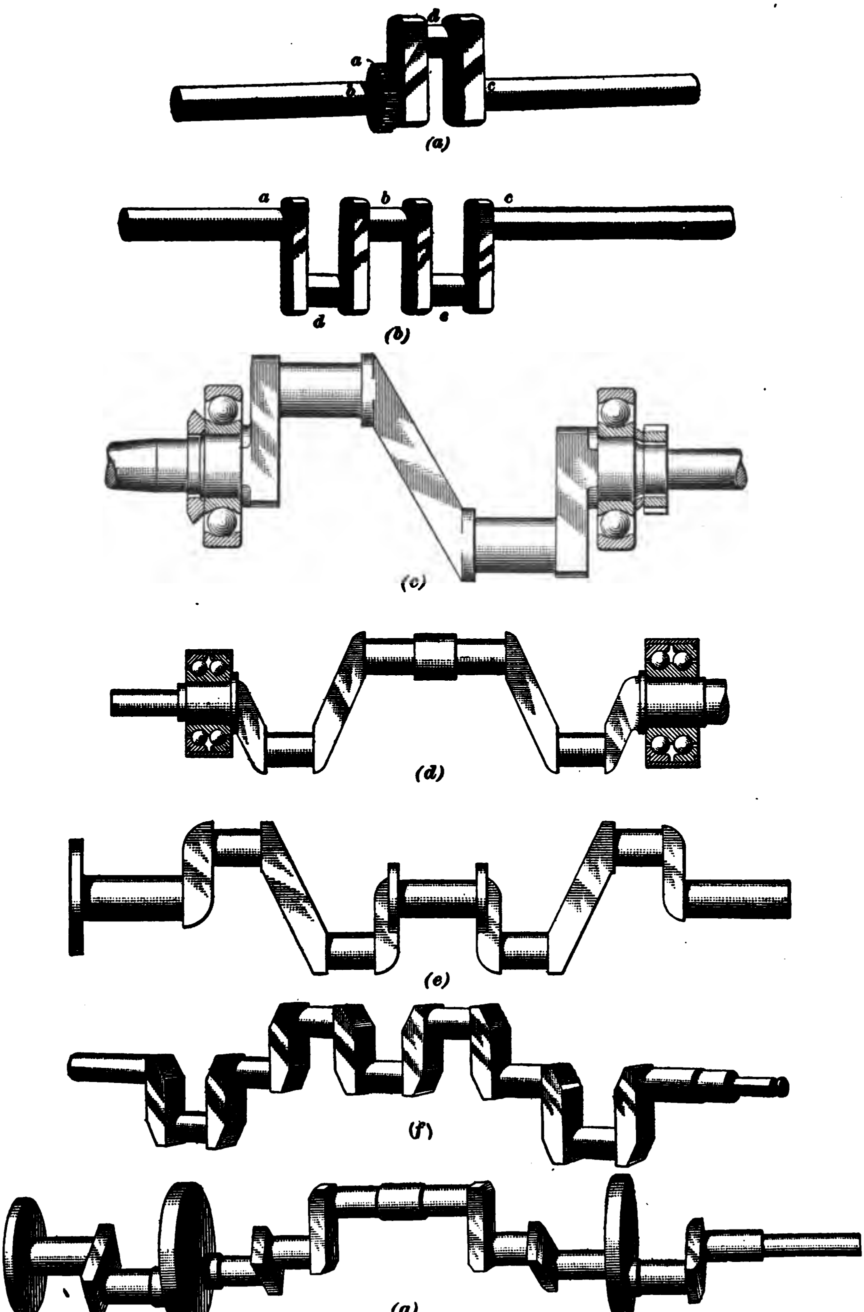


FIG. 22

as possible and yet be strong enough to resist the twisting and bending action to which they are subjected, the bearing portion being made sufficiently ample to withstand the wear due to continuous rotation at high speed. The type of crank-shaft used on single-cylinder automobile engines is known as the *center crank*, and has two arms with a crankpin between them. It is also known as a *two-bearing single-throw crank-shaft*. Such a crank is shown in Fig. 22 (*a*). The gear *a* attached to the shaft is the smaller of the pair of two-to-one gears that drive the cam-shaft. The bearings *b* and *c* of the shaft are close to the crank-arms, and the crankpin *d* connects the arms. The two ends of the shaft must be in line with each other, and the crankpin must be parallel with the shaft.

Fig. 22 (*b*) shows a crank-shaft with two center cranks for a two-cylinder engine. This is known as a *three-bearing double-throw crank-shaft*. The shaft rests in bearings at the points *a*, *b*, and *c*, and the crankpins *d* and *e* are in line with each other and parallel with the bearings. In some crank-shafts for two-cylinder engines, in which the cylinders are opposed horizontally, the cranks are set 180° apart, or opposite each other, as shown in Fig. 22 (*c*).

Three types of crank-shafts are used with four-cylinder four-cycle engines, namely, crank-shafts having two bearings, as shown in Fig. 22 (*d*); those having three bearings, as shown in (*e*); and those having five bearings, as shown in (*f*). The crank-shafts shown in (*c*) and (*d*) run in ball bearings, and all the others turn in plain bearings.

Fig. 22 (*f*) shows what is considered the correct arrangement of the throws of a crank-shaft for a four-cylinder automobile engine, in which all the parts are made as light as possible consistent with strength. The five shaft bearings serve to give a better distribution of the stresses on the shaft and make it, as well as other parts of the engine, less subject to injury from vibration.

Fig. 22 (*g*) shows a balanced four-bearing six-throw crank-shaft for a six-cylinder engine.

VALVES AND VALVE MECHANISM

VALVES

31. Poppet Valves.—A **poppet valve** consists of a disk with a stem at right angles to the plane of the disk. Poppet valves are used for the admission of the charge and the control of the exhaust. The valves open in the direction of the axis of the stems, sometimes toward the inside of the cylinder, and are held to their seats by springs. As they open inwards, they have no tendency to leave their seats during the explosion, the pressure in the cylinder helping to keep them on their seats.

The valves required for the four-cycle engine are the exhaust and inlet valves, and occasionally the auxiliary exhaust port, opened by the piston, to relieve the pressure on the exhaust valve. The valves are sometimes also called *mushroom valves*. The valve seats and valve-stem guides may be located in removable heads or in the cylinder casting, or they may be arranged in separate castings bolted to the cylinder.

The valve seats are usually made of cast iron. Nickel steel has become quite popular for exhaust valves when the head and stem are made in one piece; it is also used extensively for the heads of built-up valves having the stems made of machinery steel. It is claimed that valves made of nickel steel will neither warp nor scale from excessive heat. For the same reasons, cast-iron exhaust valves having steel stems are also often used. Some trouble has, however, been experienced in securely fastening cast-iron valve disks to steel stems, but this difficulty is largely overcome by careful machining and brazing.

The valve seats are occasionally flat, though more frequently they are beveled to an angle of 45°; an angle of 30°, however, is sometimes used. The bevel-seat type of valve is kept tight more easily than the flat-seat type, and for this reason it is generally used.

A valve that is opened by mechanical force applied by rigid parts is called a *mechanical valve*, or, less commonly, a *mechanically operated valve*. An exhaust valve of the poppet type must always be mechanically operated, because it must be lifted against the pressure in the cylinder at the time the exhaust is to begin.

The inlet valve, however, can be so constructed as to be opened by the pumping action of the piston during the suction stroke. When thus opened it is known as an *automatic inlet valve*.

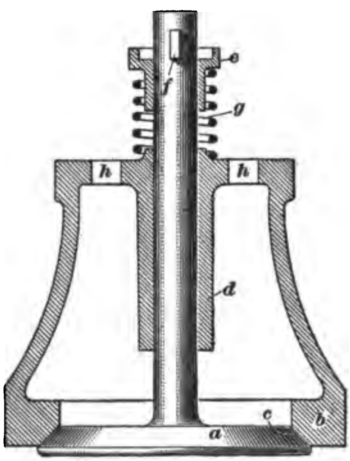


FIG. 23

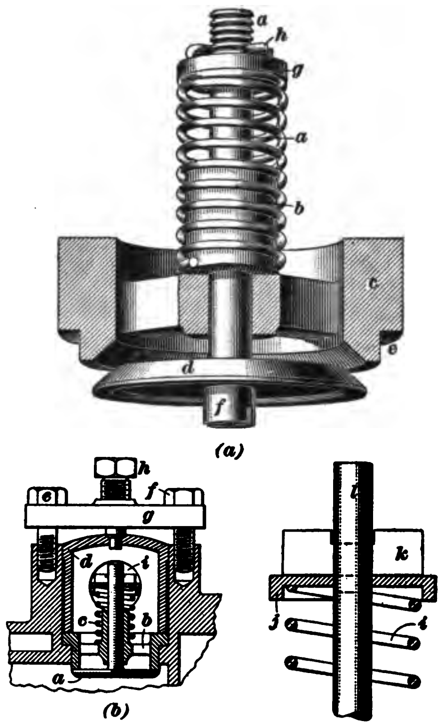


FIG. 24 (c)

32. Fig. 23 shows a removable inlet valve and its *cage*. At *a* is shown the valve; at *b*, the caging, which carries the seat *c* and the guide *d*; and at *e*, a cupped washer, which keeps the pin *f* from coming out and guides the valve spring *g*. The spring bears against a shoulder of the valve-stem guide, around which are holes *h* to provide a passage for the gas. The valve cage is usually placed in a recess in the valve chamber, with room around the valve *a* to permit a free flow of gas.

33. A common arrangement of an automatic inlet valve is shown in Fig. 24 (*a*). The valve stem *a* works in a guide *b*, which is connected by a three-armed spider to the shoulder cage *c*, against whose base the valve head *d* seats. A gas-tight fit between the valve *d* and its seat is secured by grinding. The shoulder *e* is carefully machined and fitted against an internal shoulder in the cylinder head, the joint being practically gas-tight. The cage is held in place as shown in Fig. 24 (*b*), in which the valve *a*, the cage *b*, and the spring *c* differ somewhat from those shown in Fig. 24 (*a*). The cast-iron bell, or elbow, *d* is clamped over the cage to the cylinder head and holds it down by means of the capscrews *e* and *f*, on each end of the yoke *g*, and the setscrew *h* in the middle of the yoke. The opening *i* admits the fuel to the valve and is formed to give a good passage to the incoming mixture. In the center of the valve head, shown in Fig. 24 (*a*), is a slotted boss *f*, to receive a screwdriver for turning the valve for grinding. A thin nut *g*, backed by a cotter pin *h*, retains the spring. As it takes a little time to unscrew this nut, a more common arrangement is the washer and key shown in Fig. 24 (*c*), which is used for both automatic and mechanically operated inlet and exhaust valves. The end of the spring *i* bears against a cupped washer *j*, which is retained by a thin flattened key *k* slipped through a narrow slot in the valve stem *l*. The key is so formed that by compressing the spring slightly it may be readily slipped out, but it cannot otherwise escape.

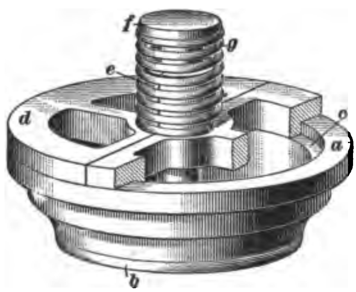


FIG. 25

34. As automatic inlet valves are always made as light as possible so as to permit a moderate spring tension to close them, difficulty is encountered in arranging a key that will itself be strong enough to stand the continual shocks to which it is subjected, and yet will not be so large as to weaken the valve stem. Inlet-valve stems with keys have but a limited life

at best, and for this reason and because it is little subject to breakage, the single-piece valve shown in Fig. 25 has found much favor. The valve seat *a* is a simple rim, suitably chamfered to the bottom to fit the beveled face of the valve *b* and having a circular recess *c* into which fits the cage *d*, split vertically as shown. The portion *e* of the cage forms the valve-stem guide. The head *f* of the valve stem is made in one piece with the valve, thus dispensing with the usual washer and key. When the parts are put together with the spring *g* in place and the cage *d* in the recess *c*, all the parts are bound together.

35. Concentric Valves.—In Fig. 26 is shown a pair of **concentric valves** arranged in the head of an air-cooled cylinder having a dome-shaped combustion chamber *a* into which the valves open.

The inlet valve *b* is of a hollow cylindrical poppet type.

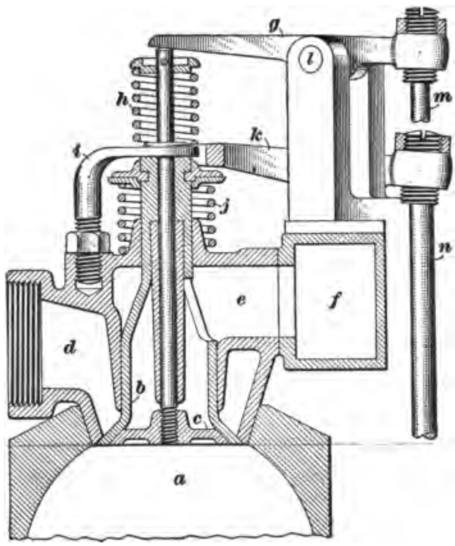


FIG. 26

The exhaust valve *c* seats itself on the inlet valve. The combustible mixture enters through the inlet passage *d*, and the exhaust gases flow into the passage *e* and header *f*. Extending through the upper part of the hollow inlet valve *b* are ports that connect the interior of the valve with the exhaust passage *e*. The stem of the exhaust valve *c* extends up through the inlet valve to the rocker-arm *g* which bears down on the end of the valve stem to open the valve at the proper time against the resistance of the exhaust-valve spring *h*, which rests on the bent support *i*. The inlet valve *b* is held to its seat by the inlet-valve spring *j*.

The action of the pair of valves is as follows, remembering that exhaust occurs just before intake: The exhaust valve is opened by pressure of the arm *g* to allow the exhaust gases to pass up into the hollow inlet valve *b* and out through the openings in its upper part into the exhaust passage *e* and thence to *f*. The inlet valve *b* is then forced down by the arm *k*, so as to bring this valve against the exhaust valve and thus close the exhaust outlet and at the same time open the inlet passage. Both valves are then allowed to rise, so as to enclose the charge in the cylinder before compression begins.

The rocker-arm *g* is pivoted at *l* and operated by the push rod *m*, which extends down to its cam on the cam-shaft. The rocker-arm *k* for the inlet valve is similarly operated by the push rod *n*. The pair of concentric valves and the cage surrounding the valves are removable from the cylinder, as indicated. The engine on which these valves are used is provided with auxiliary exhaust valves that are opened just before the piston reaches its lower dead center.

36. Sliding Valves.—Some engines of the vertical four-cycle water-cooled type differ from the majority of modern automobile engines in having **sliding valves** instead of the customary lifting valve of the poppet type. The sliding valves are cylindrical shells located between the wall of the stationary cylinder and the piston. The piston, therefore, does not come into contact with the cylinder wall, but is separated from it by the shells of the two valves. These valves are reciprocated in the cylinder to bring the ports in them to positions opposite the inlet and exhaust ports at the proper time.

37. Rotary Valves.—Comparatively few automobile engines are provided with **rotary valves.** A rotary mechanically driven valve is used in the two-cycle engine shown in Fig. 27. In (*a*) the parts are shown in place and the reference letters are the same as in (*b*), in which the valve itself is shown in detail. The valve is in the form of a disk with a port *b* cut through it. At *c* is shown the part that contains the crank-case inlet port and that forms the seat for the

rotary valve. The inlet port is shown at *d*. The valve is driven by means of a bevel gear on the short shaft *e*, which is in turn driven by a corresponding bevel gear on the shaft *f*. This shaft runs alongside the engine parallel to the crank-shaft, by which it is driven. The speed of the valve is the

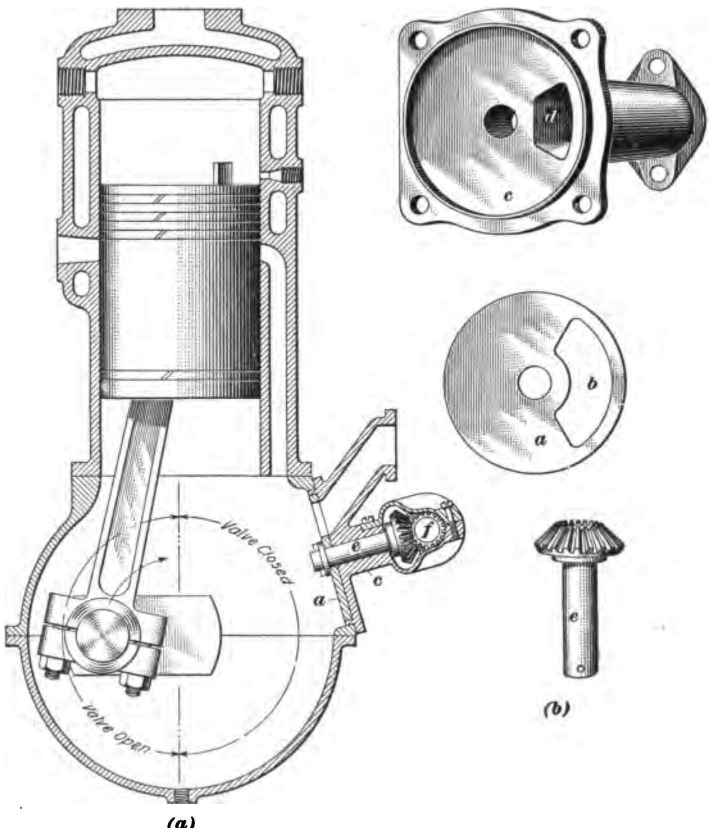


Fig. 27

same as that of the crank-shaft, and mixture is admitted to the crank-case during the time that the port in the valve registers with the port in the seat. This occurs so that the crank-case inlet is open during the inward stroke or upward stroke of the piston, as indicated by the arcs of circles in the

crank-case, Fig. 27 (*a*). If the valve opens and closes just at the ends of the stroke of the piston, as indicated, the engine can be run in either direction equally well so far as the operation of the valve is concerned.

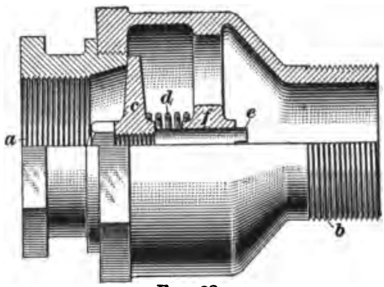


FIG. 28

38. Check-Valves for Two-Cycle Engines.—In two-cycle engines of the two-port type some kind of **check-valve** is fitted between the carbureter and the engine crank-case. One form of such valve is shown in Fig. 28. The carbureter connection is at *a*, the body of the valve being threaded at *b* for the crank-case connection. The valve *c*, which is reversible, is held to its seat by the spring *d*. The valve stem *e* has its bearing in the rib *f*, around which are openings through which the mixture flows from the carbureter to the crank-case when the piston begins its outward stroke.

39. Fig. 29 illustrates a type of **balanced check-valve,** for use on the supply piping to the crank-case of a two-port two-cycle engine. The gases pass through the valve in the direction of the arrows. When a slight vacuum is produced in the crank-case, the valve disks *a* and *b* are lifted off their seats, and the explosive mixture passes through the check-valve into the crank-case. As the charge in the crank-case is compressed, the valve disks return to their seats, thus preventing waste through loss of compression. The area of

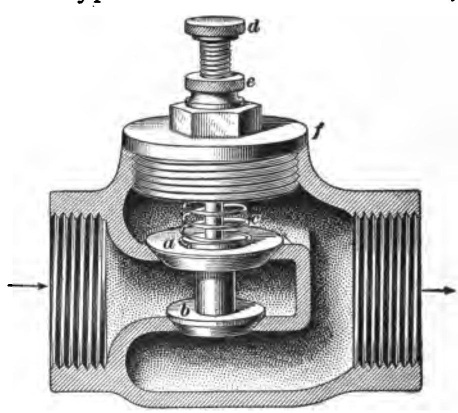


FIG. 29

the disk a is greater than that of the disk b. Thus, when a slight vacuum is produced on the outlet side, the two disks are raised against the spring c, permitting the gas to pass through. The areas of the two disks are such that the spring need not be very strong. The tension of the spring and lift of the valve disks are adjusted by means of the screw d and locknut e. The valve disks and spring may be removed for inspection or repairs by unscrewing the cap f, which is provided with a hexagonal boss, or projection, to receive a wrench.

VALVE MECHANISM

40. Valve Springs.—All poppet valves, both exhaust and inlet, are held to their seats by means of **springs**, which in turn are held in place by nuts on the ends of the valve stems, by pins passing through the latter, or by solid heads. When the inlet and exhaust valves are interchangeable, and hence mechanically operated, the tension of the springs is unimportant as long as it is sufficient to seat the valves. The amount of tension on the springs of automatically opened inlet valves is, on the other hand, an important matter. To get the greatest amount of power from an engine having an automatically operated inlet valve, the spring must be carefully adjusted to insure the required opening of the valve when in operation. In adjusting the tension of the inlet-valve spring, it is necessary to be careful that nothing is accidentally dropped into the cylinder and to make sure that the nut or pin holding the inlet-valve spring does not become loose, especially if the valve is of the inverted type.

41. Valve springs are usually made of steel, either natural or tempered, the former being wound cold and the latter being tempered after they are formed. Natural springs have the disadvantage of becoming set if subjected to hard usage, and tempered springs are liable to break.

Almost every kind and form of spring known is used on automobile engines, but the *helical spring*, or spring wound in the form of a screw thread, is used more often than any other.

Occasionally, the springs on inlet and exhaust valves are made up in the shape of a cone. Such springs are called *cone-shaped springs*. Frequently, *torsional springs*, or springs constructed to resist torsion, or twisting, are used, and occasionally *flat springs* are employed. The flat spring is likely to give poorer

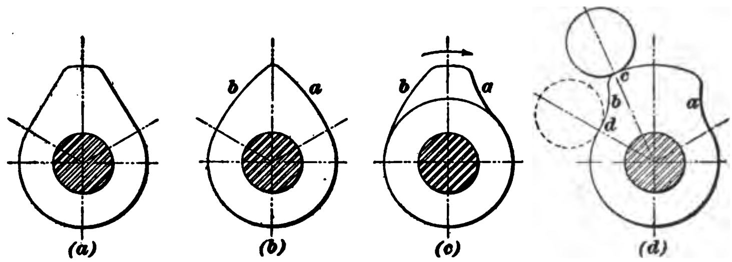


FIG. 30

results than any other type, and for this reason is less often found in practice.

42. Valve Actuating Devices.—There are several methods of operating the valves of automobile engines mechanically, but those most in favor involve the use of **cams.** As shown by Fig. 30, cams vary considerably in shape, or profile, the contour of the cam having much to do with the silent-running qualities and the efficiency of the engine.

In some cases, the cam is attached to the **cam-shaft,** which is the name given to the shaft that drives it, by means of a feather, or key, or tapered pins or setscrews. As a rule, however, especially with multicylinder engines, the cams are made an integral part of the cam-shaft, as shown in Fig. 31.

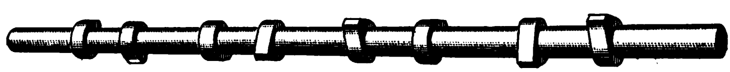


FIG. 31

43. The cam shown in Fig. 30 (*a*) is a common type, giving a fairly quick opening and closing, as well as a considerable period of full opening, of the valve and producing little noise in operation. In (*b*) is shown a cam having rising and falling shoulders *a* and *b* of convex form, giving a gradual opening

and closing and a reduced period of full opening of the valve, so that the latter is usually made of larger diameter than the valve used with cam (*a*). The cam shown in (*c*) is a combination of the cams shown in (*b*) and (*d*). The rising shoulder *a* is slightly concaved to give a rapid lift without much noise, and the falling shoulder *b* has a slightly convex shape to permit of gradual closing of the valve and to decrease the tendency to jump. As the rising and falling shoulders of the cam shown in (*d*) are concaved, a rapid opening and closing of the valve is secured. However, there is a pronounced tend-

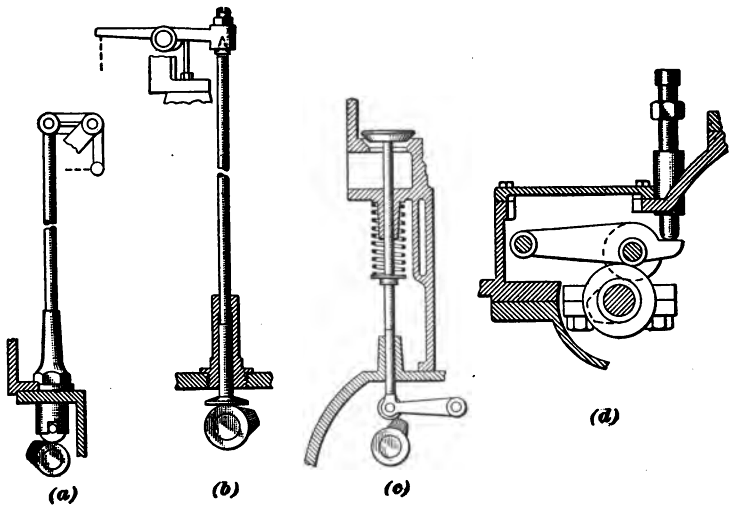


FIG. 32

ency to produce noise at high speeds, especially in closing, because, unless a very strong spring is used, the roller (shown in dotted outline) will not follow the contour of the cam, but will jump from *c* to *d*, producing much noise and causing excessive wear.

44. The cams may operate directly on the push rods, as shown in Fig. 32 (*a*) and (*b*), or through bell-cranks or levers, as shown in Fig. 32 (*c*) and (*d*). In some vertical engines, the cam-shaft, frequently called the *lay*, or *two-to-one*, *shaft*, is not located directly beneath the center of the valve stem, but

a little to one side, so that the motion of the cam is vertical instead of horizontal when it strikes the valve stem, the object being to give a quicker opening and closing to the valve than if the cam-shaft were located directly in line with the axis of the valve. The same object could also be accomplished, but not quite so readily, by using a cam of different shape. Provision is usually made for adjustment, so that the opening

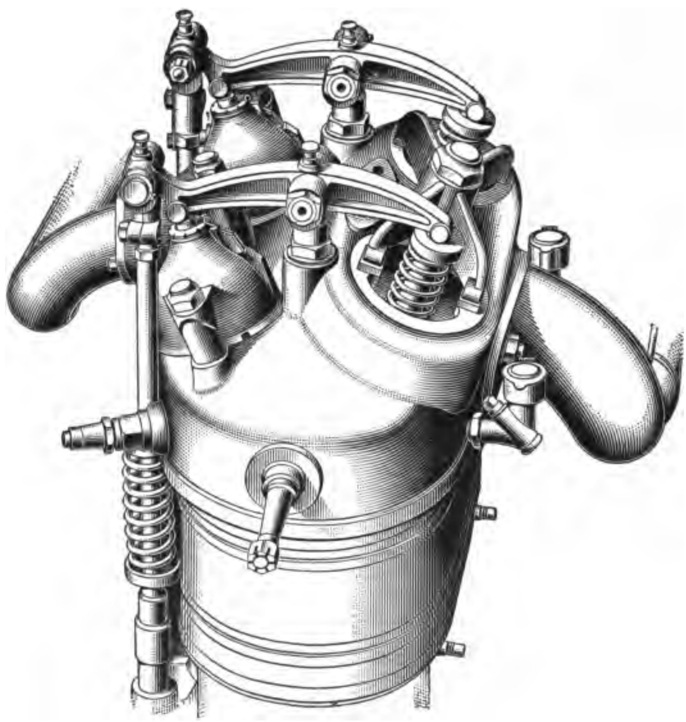


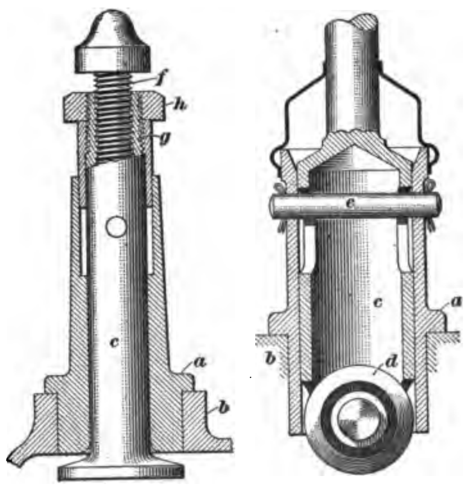
FIG. 33

and closing of the valve may be regulated to suit the speed conditions.

45. When the inlet and exhaust valves are made interchangeable, they are usually operated by a double set of cams on the same cam-shaft, or by cams on two shafts on opposite sides of the engine, the valves being covered by plugs

or held in place by clamps. If the inlet valve is mounted above the exhaust valve, both opening into the same passage, the inlet valve is usually operated automatically, although a rocker-arm actuated through the cam-shaft is sometimes employed to operate the inlet valve mechanically. Poppet valves located in the cylinder heads are frequently operated by bell-crank or other levers applied in different ways, one of which is shown in Fig. 33.

The cam-shafts should be parallel with the crank-shafts if driven by spur gears and provision should be made for wear, while the cam-shaft should be so set that each cam will perform its proper function at just the right time. It is frequently found that changing the meshing of the teeth of the gears one tooth earlier or later will secure very much better results, but such changing should never be attempted without a clear understanding of the result to be accomplished.



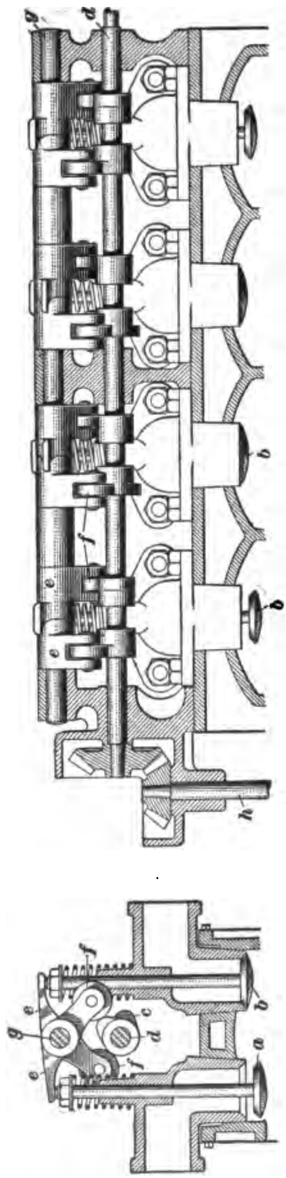
(a) (b)

Fig. 34

If the cams are to be fastened to the cam-shafts by tapered pins, the pins should fit tightly and be slightly upset on the smaller end, to prevent them from working out. If held by setscrews, the shafts should be *spotted*, or slightly flattened, under the screws, to prevent the latter from slipping from their proper positions.

46. Common forms of **valve lifters** and their guides are shown in Fig. 34. The lifter guide a at one side of the cylinder is mounted in the crank-case b, the lifter c moving up

and down in the guide *a*. In view (*a*), the foot of the lifter, against which the cam bears, is enlarged, presenting a plain, flat surface to the cam. In view (*b*), the foot of the lifter carries a roller *d* that bears against the face of the cam. The pin *e* not only serves to keep the roller *d* in the same vertical plane as the cam, but prevents the lifter from dropping into the crank-case when the cam-shaft is removed. With the lifter shown in (*a*) there is no necessity of using a pin to keep the foot of the lifter always in the same path of travel, because the lifter foot is circular in shape. Provision for adjustment of the lifter to take up wear is made by threading the parts *f* and *g*. The part *g* also has an external tapering thread; thus, when the part *h* is screwed down on it, its internal thread grips that of *f* and prevents the stem from turning.



(b)

(a)

FIG. 35

47. The **bevel gears** and **cams** of the valve-operating mechanism of one type of four-cylinder four-cycle automobile engine are shown in Fig. 35, (*a*) being a sectional end view and (*b*) a front view. The inlet and exhaust valves *a* and *b*, Fig. 35 (*a*), are interchangeable and are mechanically operated by means of cams *c* on the cam-shaft *d*. The cams operate the valves

through bell-crank levers *e*, provided with steel rollers *f* and mounted on a fulcrum shaft *g* on which they turn. The cam-shaft *d* is driven by means of bevel gears attached to the shaft *h* and meshing with similar gears on the crank- and cam-shafts, as shown in (*b*).

MISCELLANEOUS ENGINE FITTINGS

COMBINED PRIMING AND RELIEF COCKS

48. A cock by means of which the pressure in the cylinder due to compression may be relieved when starting the engine, and which also serves as a priming cock, is shown in Fig. 36. It consists of a circular plug *a* carefully ground to fit the tapering, or conical, socket in which it is turned by means of the handle *b*. The cup *c* is sufficiently large to hold the required amount of gasoline for the priming charge when the engine is to be started. The plug *a* is held in place by a phosphor-bronze spring *d* placed between two washers *e* and *f*, and a pin *g* serves to hold the whole together. The tension of the spring *d* is sufficient to hold the plug firmly in position and to take up wear, thus preventing loss of compression by leakage. The spring also serves to keep the plug tight under heavy vibration. In using this plug, the gasoline for priming is poured into the cup *c* and the cock *a* is turned so as to permit the gasoline to flow into the cylinder either before the engine is started or during the suction stroke. The cock is then left open while the engine is turned over in starting.

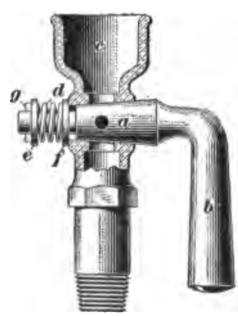


Fig. 36

GASOLINE STRAINERS AND TRAPS

49. To keep out particles of dirt, and particularly water, all gasoline should be carefully strained when poured into tanks and when run into carbureters. To accomplish this

purpose, the funnels used in filling the tanks should be fitted with fine-wire gauze about one-third the way to the top. As an additional safeguard, a piece of chamois skin may be used to prevent water and dirt from passing into the tanks. The devices shown in Figs. 37 and 38 are used to strain the gasoline as it flows from the tank to the carbureter, and should be placed at the lowest part of the gasoline pipe between the tank and the carbureter. They are of comparatively little use unless cleaned out frequently. In the one shown in Fig 37, the gasoline flowing through the inlet *a* must pass through the strainer *b* and thence to the outlet *c*. Being mounted in

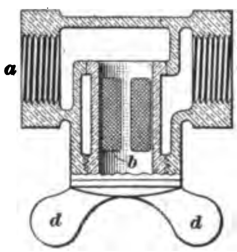


Fig. 37

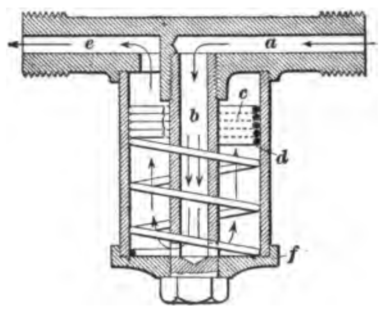


Fig. 38

a screw-cap *d*, the strainer may be readily removed for cleaning by unscrewing the cap. Fig. 38 shows a strainer in which the gasoline passing through the inlet *a* flows downwards through the center tube *b* and out into the body of the strainer, which serves as a dirt and water trap. The gasoline filters upwards through four gauze strainers *c*, held in place by the spring *d*, and passes to the carbureter through the outlet *e*. The strainer may be cleaned by unscrewing the center tube *b*, the lower end of which is hexagonal and holds the cap *f* of the strainer in place.

GASKETS

50. In order to make the joints of an automobile engine air-tight, a packing, or **gasket,** is placed between the two parts forming the joint. The materials used in making such

gaskets are usually copper, lead, asbestos, brown paper, wire gauze, etc., or combinations of these materials. Gaskets containing rubber should never be used around a gasoline engine or in gasoline-supply piping, because rubber is more or less soluble in gasoline. In the water-supply and discharge piping, rubber gaskets are frequently used, but it is much better to use *ground-joint unions;* that is, unions in which the joint is made by metal surfaces ground together. This form of joint is also used in gasoline piping, where gaskets of any description are dangerous.

The use of a gasket material composed largely of brass-wire gauze and asbestos is increasing rapidly. When properly fitted and provided with graphite facing, such a gasket will, with care, last a long time. Combined copper and asbestos ring gaskets are also well adapted for use in recessed places under inverted inlet valves, screw plugs, valve bonnets, etc. This form of gasket consists of compressible, elastic packing encased in soft-rolled copper, which makes a lasting joint under high pressures and temperatures.

BOLTS, SCREWS, STUD BOLTS, AND COTTERS

51. Bolts are used for fastening the different parts of the engine together wherever a strong joint is required, unless the construction of the part is such that bolts cannot be used.

Generally speaking, it is much easier to split and remove a rusted nut from a bolt than to drill out the rusted end of a capscrew that has been twisted off when trying to remove it from the part into which it was screwed.

Capscrews and **tap bolts** have a thread on one end and a hexagonal head on the other. They are sometimes used where it is difficult or impossible to use a bolt and a nut. Where two parts are to be fastened by a capscrew, a hole is drilled through one part and a smaller hole is drilled and tapped into the other. The parts are put together, and the capscrew passed through the larger hole and screwed into the tapped part.

Setscrews are used for fastening collars or couplings to shafts, or for fastening other temporary connections. The heads are often square and sometimes of other shapes. The points may be conical, flat, ball-shaped, or cup-shaped, and when screwed into place they will prevent the parts from slipping. The shaft should have a small depression where the setscrew strikes it, so that the setscrew will take a better hold and not cause a burr to be formed on the shaft.

Stud bolts are rods of wrought iron or steel with threads cut on both ends. One end is screwed permanently into some part of the engine to hold in place another part—such as a brace, a cylinder head, or a valve cage—by means of a nut screwed on the other end of the stud bolt. As the parts into which these stud bolts fit are frequently made of cast iron, they sometimes rust solid; but constant removal of the loose parts tends to destroy the threads on the free ends of the stud bolts and hence to produce trouble from leakage.

Spring cotters, or **split pins,** are used on bolt or stud nuts to prevent them from jarring loose and from working off entirely. They should be used wherever loose bolts or nuts are liable to prove harmful.

COLLARS

52. Collars are generally used to prevent or limit endwise motion of revolving or reciprocating parts. They are either solid or split. *Solid collars* may be held in position by setscrews, taper pins, or other devices, or they may be used loosely on shafts to keep other parts at a distance.

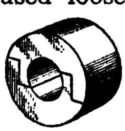


Fig. 39

Split collars are made in halves and are held together by pins or screws, as shown in Fig. 39. Although split collars are not so strong as the solid pattern, they are frequently very convenient and are often used in automobile-engine practice. The split collar has the advantage over the solid form in that it can be put into place anywhere in a space equal to twice its width, while the solid form must be slipped over the end of the part on which it is to be fastened.

ENGINE MANAGEMENT

CARE OF AUTOMOBILE ENGINES

GENERAL INSTRUCTIONS

53. The ordinary care of a good automobile engine, when everything is working well, is a very simple matter, and comprises hardly anything more than due attention to lubrication, occasional testing of the batteries, with recharging or replacement as required, and seeing that the radiator or water tank is kept full. All the oil supplied to the lubricator and oil cups should be strained, though. As the lubricator itself is probably fitted with a strainer, no additional attention at this point is likely to be required beyond occasionally taking out and cleaning the strainer. If any dirt, bits of wood, or fibers of waste get past the strainer, they are liable to cause trouble if the oil is fed through any kind of check-valve or needle valve. Waste is particularly troublesome in this respect, as it shreds, and a few fibers of it may very easily get into the oil without being noticed.

54. If the engine is fed from a mechanical oiler, the oil pipes should occasionally be disconnected near the engine, and the engine run or the pump worked by any other available means, to determine whether or not the oil is feeding properly. Most individual-pump oilers are operated by eccentrics, which work against stop-screws attached to the plungers, and the stroke of the plungers is adjusted by turning these screws to allow more or less lost motion between them and the eccentrics. The operator should learn, by experimenting with the particular kind of oil he uses, what is the least stroke for each pump that will lubricate the engine properly. If there is any great difference between the strokes thus

determined, it is probable that there is leakage either in the packing around the plunger that demands the longest stroke for the oil feed or in the check-valves. This leakage should be investigated at once.

If the oil is not fed to the pistons in sufficient quantity, the engine will make the fact known by a laboring sound and a falling off in power when both the ignition and the carbureter are in perfect order. If this occurs, a little extra oil may be put into the crank-case, where it will be thrown up into the cylinders in sufficient quantity to ease the engine until the oiler can be readjusted. A new engine should have a little more oil on both pistons and bearings than one that has run several hundred miles, and it is well to feed oil to the former until a little white smoke shows in the exhaust. Black smoke indicates too much gasoline in the mixture.

55. As elsewhere explained, it is best to use the heaviest oil that the weather conditions will permit. Often it will be found that a heavy oil can be used in summer and a medium or light oil substituted in winter without a change of lubricator adjustment, owing to the light oil flowing more freely. Generally, however, an increase in feed is necessary when the lighter oil is substituted.

56. It is well to squirt a few drops of kerosene into each cylinder at the end of a run of 75 to 150 miles. This will loosen any carbon deposit that may have formed about the piston rings. Kerosene is a very efficient solvent of the tarry products that act as a binder for this carbon deposit, although, of course, the carbon itself is not dissolved. Most engines have compression relief cocks on the cylinder heads that may be used for introducing the kerosene; but if these are absent, the kerosene may be injected through the inlet valves.

57. If the splash system of lubrication is used, and the oil is fed to the crank-case by a hand pump on the dash, this pump should be operated every 25 miles or so, depending

somewhat on the amount of low-gear driving required. Generally, there is a shut-off valve between the pump and the crank-case that must be opened by hand before the pump is operated.

An improved arrangement that obviates failure of check-valves connected with the hand pump to do their duty consists of a three-way hand valve that in one position admits oil to the pump and in the other permits the oil to pass from the pump to the crank-case. This valve is operated by hand for each stroke of the pump. The pump, of course, is of a fair size, so that two or three strokes are sufficient. Once in, say, 500 miles, all the oil should be drawn off from the crank-case, the case washed out with kerosene, and fresh oil put in, as it gradually fouls from carbon passing the piston and also gathers grit worn from the bearings.

58. Beyond attention to the lubrication, the daily care required by an automobile engine is simply the brief regular inspection to see that everything is working properly. If a battery is used for ignition purposes, it will need replacement once in a while, and the operator should keep himself informed of the battery's condition by occasional tests, so that he will not be unexpectedly stranded. The tremblers on the spark coils require occasional adjustment, and the operator should notice the sound of each one, and, if necessary, file the contact points square or readjust the springs or contact screws until the sound is correct.

59. Occasionally, the spark plugs will foul and require cleaning or replacement. How often this will occur is altogether a question of the particular carbureter used, lubricating arrangements, and type of plug; and the only general directions that can be given are that the operator should adjust the lubricator and the carbureter to produce as little free carbon as possible in the cylinder, and then should learn by trial how often the plugs require inspection.

60. If the car is used in cold weather, special attention must be given to the lubricating and cooling systems. One

item in the daily care of an engine that cannot well be neglected is the listening for knocks or unusual sounds. These may occur from a great variety of causes, which will be fully treated in *Troubles and Remedies*, Part 1. Nearly all the causes that produce knocking grow rapidly worse if not attended to, and therefore no symptom of this sort should be neglected.

STARTING AND STOPPING

61. The regular order for starting an automobile engine is given in the following paragraphs. This order should be followed every time the engine is started, for this is the best way to avoid forgetting things; in fact, the beginner will do well to memorize these instructions.

1. Open the main gasoline valve at the tank. If the tank is hung low, and the gasoline is lifted to the carbureter by air pressure, ascertain—by priming the carbureter if necessary—whether or not the tank has the required pressure, and, if necessary, pump air into it by hand. A hand pump for this purpose is mounted on the dash, usually at the left end. Sometimes the gasoline passes through a small auxiliary tank on the dash, and this tank holds enough gasoline to supply the carbureter by gravity until pressure from the exhaust gases can be raised in the main tank.

2. Retard the spark as far as possible. This is of the first importance, as an attempt to start with the spark advanced may result in a broken arm. An excellent rule is never to turn the starting crank, even when it is thought that no explosion can occur, without first making sure that the spark lever is retarded.

3. Set the throttle about one-quarter open.

4. Close the switch and insert the safety plug, if one is used.

5. Turn on the oil feed. It is assumed that any oiling and filling of oil cups done by hand has already been attended to.

6. Open the compression relief cocks, if necessary, in order to relieve the compression.

7. Prime the carbureter by depressing the float or otherwise, according to its construction. If the engine has been stopped for not more than an hour or two, or sometimes longer, this is not necessary. If the tank has pressure feed, and the carbureter has been primed to test the pressure (see 1), it does not need to be primed again.

8. Engage the starting crank, and turn it over until the resistance due to the compression stroke is felt. If the starting crank is *not* now on its upward stroke, move it backwards a quarter or a half turn until it is, and reengage the ratchet at this new point. *Never push* the crank over the compression stroke. Even if the switch is open, a hot engine may start from preignition, and a "back kick" may result in a broken arm.

9. *Pull* the starting crank upwards smartly against the compression. The engine may start. If it does not, turn the starting crank until the next compression stroke comes, and pull the crank upwards smartly as before.

62. If the carbureter has not been primed too much or too little, the engine should start unless the gasoline is too cold to vaporize. If it does not start with the second or third trial, prime the carbureter again and repeat the operation. If the engine still refuses to start, something may have been neglected or forgotten. It may be that the gasoline is not turned on, that there is no gasoline in the tank, or that the gasoline is stale or heavy, that the switch plug is not in place, that the battery is not strong enough, or that the method of priming the carbureter has given too light, or too weak, a mixture. The method of priming is something that will depend on the individual carbureter, and can only be learned by experience.

63. The procedure for stopping an automobile engine is to close the throttle partly, so that the engine will run slowly, and then open the switch. If the stop is permanent, take out the safety plug, shut off the oil feed, and shut off the gasoline at the tank. If the car has been run some distance, it is

well to squirt a small amount of kerosene through the compression relief cocks to loosen any carbon deposit that may have gathered around the piston rings.

INSPECTION AND TESTING OF ENGINE AND AUXILIARIES

64. When an automobile engine and its attached auxiliaries are about to be inspected and tested, attention should first be given to the steps necessary to be taken in order to expose, for examination, the working parts of the engine, such as the two-to-one gears (if these are enclosed), the pump, the cams, the igniters (if these are of the contact variety), the magneto (if any), and the interior of the crank-case, so far as this can be reached without dismantling the engine. On completing this preliminary investigation, the various parts should be examined in detail and their condition determined.

65. The float valve of the carbureter should be tested for leaks by opening the valve between it and the tank and looking for gasoline drip. If gasoline escapes, the float may be set so high that it does not close the needle valve before gasoline issues from the spray nozzle; or, possibly, the valve itself may leak.

At this stage, it is well to assume that the float is properly adjusted, and to begin by shutting off the main gasoline valve and then unscrewing the washout plug below the needle valve. An investigation may show that dirt, waste, or a splinter of wood has got past the strainer, through which, presumably, the gasoline passes on its way to the float, and is lodged in the needle-valve opening. It may be of advantage to open the top of the float chamber, which can usually be done without disturbing other parts, and take out the float and needle valve. A little gasoline washed down through the needle-valve orifice will then generally carry away any dirt that may have clung to the valve when the plug was unscrewed. If the gasoline still drips when the parts are reassembled, the mixing chamber should be opened and the top of the spray nozzle examined to see whether gasoline

is escaping from it. An electric light should be used in making an examination of the carbureter, as, with any other illuminant, a fire might be started. The portable electric flashlights sold everywhere at a moderate price answer the purpose very well.

66. If gasoline is escaping from the spray nozzle, the needle valve of the float may be carefully ground in by placing between the valve and its seat a paste made of powdered grinding material and oil or water, using for this purpose either very fine sand, or, preferably, pumice or rotten stone. The method of regrinding valves will be explained more fully in *Troubles and Remedies*, Part 2. Emery should not be used, as it will embed itself in the brass valve or seat. A little of the sand or pumice should be mixed with oil to make a paste. The mixture is applied to the needle point, which is then rotated by quarter turns in its seat with slight pressure, taking care to keep the stem as nearly vertical as possible and frequently adding fresh paste.

If regrinding does not stop the leaking, it is likely that the float is too high; but, unless the gasoline escapes very rapidly, the float had better not be disturbed until attention has been given to other more important details. The car, however, should not be left standing with the main gasoline valve open, for the dripping gasoline may catch fire from the lamps, from a stray spark in the ignition circuit or at the timer, or from a lighted match accidentally dropped near the valve.

The manner of adjusting the carbureter should be noted, but the adjustment should not be disturbed unnecessarily, as it is often difficult to get the right mixture after this has been done.

67. Next to making sure that there are no gasoline leaks, the most important thing is to see that no bearings are too tight or have seized, owing to lack of oil or to the bending of the shaft or connecting-rods. The compression relief cocks should be opened and the shaft turned over slowly by hand. The shaft should move with entire freedom, a little more

easily at the beginning and end of the piston stroke than at mid-stroke, because of the slower movement of the piston at the ends of the stroke, but with no binding or sticking at any point. If the shaft turns hard, the car should be taken to the repair shop, because probably either the bearings or the pistons are cut, or the shaft or rods are sprung out of true, as for example, from having struck a loose nut or other obstruction in the crank-case or from preignitions in the cylinders. Fortunately, serious trouble of this sort does not often occur.

At the outset, it is well to locate all loose bearings, as these require more lubrication than properly fitted bearings. If they are very loose, there is a strong likelihood that they have been cut, in which case they ought to be opened, scraped, and refitted at the earliest possible moment. Of the main-shaft bearings, the one next to the flywheel is the most likely to be loose. If the engine is vertical, a jack may be put under the flywheel and the jack-lever worked gently up and down to disclose looseness, if any, in this bearing.

68. To expose the crankpin bearings of a vertical engine, it is sometimes necessary to take down the bottom half of the crank-case, which is generally attached to the upper half by capscrews or studs, and which simply serves the purpose of an oil pan. Under this arrangement, the shaft bearings are usually supported from the upper half of the crank-case, which is itself supported on the frame of the car. Nevertheless, when slackening the screws or the nuts on the studs, it is advisable to find out whether or not they are carrying the weight of the crank-shaft. This can be done by slackening all the screws several turns, and then pushing upwards against the oil pan with the hand to see how much pressure is necessary to lift the pan off the screws. If the shaft is found to be resting on them, it should not be taken down at once, unless the main-shaft bearings themselves need attention. Generally, if the shaft is supported by the bottom half of the case, the crankpin bearings can be

reached from handholes located in the bottom or sides of the crank-case.

The crankpin bearings can be tested for tightness by setting the engine at mid-stroke and oscillating the flywheel very gently back and forth while the fingers of one hand are resting on the edge of the crankpin bearing. A slight looseness may be allowed, provided the lubrication is sufficient and there is no cause to suspect that the bearings have been cut. The amount of permissible looseness will depend to a great extent on the particular engine and the speed at which it is to run. A vertical four-cylinder engine running at moderate speed will bear as much as .002 inch of lost motion on the crankpins, but if the same engine is run at a high speed, this amount of lost motion will be too much.

69. The main-shaft bearings will bear less lost motion than the crankpins, and if one bearing is worn more than another, as is likely to be the case, it will result in one-sided wear of the crankpin bearings, due to the settling of the shaft. The main-shaft bearings ought not to have more than .001 inch of play before being taken up, but more than this is often found.

A double-opposed horizontal engine will, sooner than any other type, develop a pounding sound, generally called a *pound*, at the main-shaft bearings, because the explosions occur alternately in opposite cylinders and there is nothing to keep the shaft against one or the other side of its bearings.

70. In addition to the inspection for loose bearings, the principal nuts and screws should be tested to see that they are tight, and if any cotter pins are missing from bolts, studs, or slotted nuts, they should be supplied at once. The bolts on the crankpin bearings should also be examined for tightness and to see that cotter pins are supplied.

71. If the inlet valves are automatic, it should be seen that they work freely in their guides, that they do not leak, and that their springs are not too weak. If there is more than one cylinder, the inlet-valve springs must be alike in tension. If

the valves stick, they may be freed by squirting a spoonful of gasoline on them. If they leak, they should be ground in.

The openings of the valves should be determined to some extent by their diameters. Valves up to 2 inches in outside diameter generally lift about $\frac{1}{8}$ inch, and slightly more than this if they are larger. The keys through the valve stems should be examined to see that they are not on the point of breaking.

The tensions of the valve springs on similar valves of the same engine should be equal; their equality may be tested by pressing the ends of the valve stems together while the valves are held by their cages, as explained in *Troubles and Remedies*, Part 1.

72. The operator should satisfy himself regarding the lubrication of every part of the engine. Every oil pipe should be traced, and every oil cup and oil hole located and the purpose of each ascertained. Oil pipes leading from the automatic lubricator should be disconnected close to the bearings or cylinders, and the lubricator worked by hand to see that it is feeding properly. Generally, this can be done by working the pump plungers up and down to the extent of the lost motion on the pump eccentric. If this cannot be done, the delivery of oil may be watched after the engine has been started.

If an oil pipe is clogged, it should be disconnected close to the lubricator; and if no oil comes from the lubricator at that point, the cause of stoppage should be located. The trouble will probably be found to be caused by dirt or waste under the check-valves of the pump. If oil comes from the lubricator when the pipe is disconnected, the latter is stopped up, and can be cleaned by running a wire through it. Generally, however, any obstruction of this sort will travel to the end of the pipe and lodge in the check-valve, if there is one at that point, so that the check-valve should be unscrewed and examined.

73. The manner in which oil is supplied to the crankpins should be ascertained, because these are sometimes fed

simply by internal splash and sometimes by centrifugal ring oilers and oil passages drilled through the cranks. If internal splash is relied on, the operator should see that the crank-case contains enough clean oil to allow the connecting-rod caps to dip into it about ½ inch at the lower end of their stroke.

If the car has not been used for a considerable time, the oil in the crank-case, oil cups, and reservoir is likely to be stiff and gummy. If this is the case, the oil should be drawn off and a moderate quantity of kerosene used to make sure that the oiling system generally is thoroughly clean. Before starting the engine, a liberal supply of fresh oil should be provided, as the kerosene will cut away the old oil wherever it reaches, and the pistons, cylinders, and bearings might become cut before the fresh oil from the reservoir can reach them.

When oil has not been cleaned out in this manner, it is a good precaution, on general principles, to put a pint or a quart of fresh oil into the crank-case. If, however, on starting the engine it is seen that a considerable quantity of white smoke is being produced, the crank-case has evidently too much oil, and a portion should be drawn off.

74. The ignition circuit should next be gone over. This examination should be made with the switch closed and the safety plug—that is, a plug the removal of which will break the circuit—if one is used, inserted in the switch or coil, the gasoline shut off, and the compression relief cocks (if any) open. The positions of the lever that controls the spark for early and late ignition should be ascertained by a careful examination of the timer, and, to obviate any accidental explosion in the cylinders, the lever should be set for a late, or retarded, spark. The engine should be turned over slowly, and the sound of each of the vibrators on the coils noted. The sound should be clear and regular, and fairly high without being tinny. If necessary, the contact screws, or the tension screws, if there are any, of the vibrator springs should be adjusted until the vibrators sound alike.

75. The timer should be examined to see that the contact segments are not badly pitted by the spark at the leaving edge. If they are pitted, or if the fiber or hard rubber adjacent to them is roughened by the sparking, the timer should be cleaned up as well as possible with a piece of sandpaper or a file, and the first opportunity taken to true it in a lathe. If the timer is rough, the contact roller or fingers will jump and give very erratic contact when the engine is running fast.

The spark plugs should be unscrewed and their condition determined. They will not have to be taken apart unless they need cleaning, or unless it is discovered that the porcelain is broken, which will be evident by a looseness of the outer end. If the porcelain is broken and there are spare porcelains at hand, the bushing may be unscrewed and a new porcelain and gasket inserted. Usually, it is impracticable to use the old gasket a second time, as the bushing has to be screwed down so tightly as to endanger the porcelain. The bushings should be set down enough to prevent leakage past the porcelain, but no more.

76. The gap between the spark points should not be greater than $\frac{3}{64}$ inch for the best possible spark. The points should be presented directly to each other, and should be filed true and square. The spark will not be so intense if it jumps between needle points. If necessary, the porcelains should be cleaned. To do this properly, it is generally necessary to take the plug apart. The porcelains are cleaned with a cloth or brush wet in gasoline. If the carbon deposit is very hard, it may be loosened with fine emery cloth and the cleaning finished with gasoline and a cloth. In assembling the plug, care should be taken that the spark points are properly located.

77. The battery may be weak and may have to be recharged or replaced. If dry cells are used, it is likely that some of them are weaker than others. The only way to determine this is to use a *battery tester*, which is a small pocket ammeter through which the cell may be momentarily short-

circuited. The battery as a whole may be tested by disconnecting one of the secondary cables from the spark plug and noting the length of the spark in the open air. The spark should be at least $\frac{3}{8}$ inch in length—$\frac{1}{2}$ inch is better. The coil should not be worked with the detached cable held so far from the engine that no spark can jump, as this is liable to tax the insulation of the secondary winding.

78. Having gone over the engine, it may be started, to determine whether the ignition and carbureter adjustments have been made properly. Set the throttle so that the engine does not run excessively fast, and listen to the sounds it makes. Any knocking sound should at once be traced to its source and eliminated. The sound may be due to a loose mud-guard or something of the sort on the car, which of course does not affect the engine; or, it may be found in the loose coupling between the clutch and the gear-shaft, but this coupling is intended to be loose and will give no trouble. Any knock due to a loose bearing or loose bolt, however, should receive attention at once. It may be found that the engine will run light, that is, without driving the car, and with the throttle nearly closed without developing a knock, but may knock badly when under load. This subject is taken up in *Troubles and Remedies*, Part 1.

79. The sound of the impulses, as well as that of the exhaust at the muffler, should be listened to. If the engine has several cylinders, the impulses should be equally timed and should take place with equal force. If, with the spark somewhat retarded, the impulse is more energetic in one cylinder than in another, there will be a muffled sound to some one or more of the explosions. Differences in the explosion effects produced may result from too early ignition or may be due to a deposit of carbon that also ignites the mixture so that the charge is burning from two points at once and consequently more rapidly than it should. Actual preignition, that is, too early ignition, due to carbon deposit, seldom occurs when the engine is running light, but may occur when the car is being driven over a sandy road or up a long hill. If early ignition

in one cylinder is due to faulty timer adjustment, the difficulty may be corrected in some one of several ways, according to the construction of the timer. Sometimes the adjustment must be made by filing the contact segments. This, however, should be attempted only as a last resort, after it has become evident that the trouble is not due to heated carbon in the cylinder or to causes that can be corrected in some other way.

80. If the inlet valves are automatic, they are likely to work unequally when the engine is running light with the throttle nearly closed. Under these conditions, the most careful equalizing of the springs will not prevent one or two cylinders from assuming most of the work, because the force available to open the valves is small. Often, an engine will run on one or two cylinders for some time in this manner, and then for no apparent reason some other cylinder will start working and the first will stop. As soon as the throttle is opened, all the cylinders begin to work alike.

81. When the engine is running light, a late ignition in one cylinder will show itself by a louder exhaust from that particular cylinder, owing to the slower combustion of the charge and the consequent higher pressure when the exhaust valve opens. The remedy for late ignition is practically the same as for early ignition, any adjustment of the timer being, of course, in the opposite direction.

82. A quick method of testing the spark timing is as follows: Shut off the gasoline, retard the spark as far as possible, and open the compression relief cocks. Turn the crank slowly by hand, letting the air escape through the cocks so that the compression will not cause the pistons to run ahead, which would take up the slack between the crank-shaft and the timer, thus giving a false result. Note the position when the vibrator begins to buzz, and mark the rim with chalk or in some other way. Now turn the crank, *always forwards*, until the next vibrator begins to work, and again note the flywheel position. If the engine has four cylinders, or two vertical cylinders with opposite cranks, the new

position should be exactly one-half turn from the old. If the engine has two opposed cylinders, or two vertical cylinders, with the cranks together, the flywheel should have made exactly a complete revolution. If there are three cylinders, the marks on the flywheel should be one-third of the rim circumference apart. Many modern cars have the flywheel rims already marked to indicate the top and bottom positions of the cranks, and these marks may be used, as the spark should occur exactly at the outer or upper dead center when fully retarded.

If the spark timing is found to be very irregular, the best plan is to attend to it at once. In any case, irregular timing should not be neglected, as it involves a considerable loss of power.

83. While the engine is running, note whether the cooling water is circulating properly. The engine should be able to run indefinitely with the throttle just open and the spark about one-half advanced, without the radiator heating up excessively, provided the latter has a fan to assist its cooling. If, on taking the car out on the road, it is found that the radiator is persistently overheated, the cause of such overheating should be investigated. The trouble may be found to be due to a clogged pipe, dirt or oil on the inside or the outside of the radiator, a defective pump, clogged radiator tubes, etc. The operator should always see that there is plenty of water in the radiator before starting on a trip, as a deficient supply will cause overheating.

AUTOMOBILE OPERATION

CONTROL OF AUTOMOBILE

GENERAL INSTRUCTIONS

MANIPULATION OF SPARK AND THROTTLE LEVERS

1. The manipulation of the spark and throttle levers that control the speed and power of the engine is one of the most important things to be understood by the driver of a gasoline motor car. Let it be assumed that a car is traveling along a good level road and that the spark and throttle are properly set to accord with the speed and the power required.

The speed can be decreased either by partly closing the throttle or by retarding the spark. But, in general, neither of these methods alone will answer if the speed is to be decreased any great amount, especially if the car is to be run at the decreased speed for some time. If the speed is decreased simply by retarding the spark, the gases escaping from the engine will be extremely hot when they enter the exhaust pipe. In some cases when the retarding of the spark is excessive, the gases are still burning so that a flame passes out into the exhaust. Under any condition, the late burning due to a retarded spark heats the engine unduly. This will generally be evidenced in a short time by the boiling of the cooling water in the case of a water-cooled engine. The exhaust pipe also becomes hot, sometimes even red hot, when the throttle is well open and the spark retarded so as

to be very late. Aside from the heating effects just mentioned, the gases are injurious to the exhaust valve and sometimes to the valve seat.

On the other hand, if the spark is left unchanged and the throttle is closed for decreasing the speed and power of the engine, then, as the speed decreases, the ignition will be too early, provided it was properly set for the higher speed, as has been assumed. If the car is slowed down very much, the ignition may occur so early as to have a tendency to drive the engine backwards, thus decreasing the power so much as to cause the engine to stop. The early ignition at the slow speed will generally cause a knocking or pounding sound in the engine, except in possible cases where the machine is quite new and the parts are very snugly fitted together. This pounding or knocking is an indication of heavy stresses in the engine, and these stresses, of course, are injurious to it. The spark lever should never be left in such a position that ignition will take place early enough to cause pounding.

2. Method of Decreasing Speed.—The correct way to decrease the speed of the engine is to close the throttle and to retard the spark. Naturally, the first step is to close the throttle and then to retard the spark as the speed decreases. If the car is to run for some time at the slower speed, the throttle is then opened somewhat and the spark gradually advanced to maintain the desired slower speed. The final adjustments are made by gradually closing the throttle somewhat and also advancing the spark until the positions of the two are such that the throttle is closed as far as possible and the spark advanced as far as it will go without producing pounding or causing a decrease in the power of the engine. Of course, it is a matter of trial to find the best setting, and this can generally be attained only after some experience has been gained by the driver.

3. Method of Increasing Speed.—To speed up the car quickly again, the spark, if far advanced, should first be retarded somewhat and the throttle then opened. This

opening of the throttle can be to the full extent if it is desired to gain speed as rapidly as possible. As the speed increases the spark should be advanced, always keeping it at the position that gives the greatest turning effort, or power, for the corresponding speed of the engine. After the car has reached the desired speed, the throttle can be closed gradually, and the spark advanced at the same time, until the positions of least opening of the throttle and greatest advance of the spark that will maintain the speed without pounding have been obtained.

4. Adjustments for Hill Climbing.—In climbing a hill after the car has been running on a good level road with the proper setting of spark and throttle, the adjustments are practically the same as when increasing the speed on a level road; that is, the spark is first retarded slightly and the throttle then opened so as to maintain the desired rate of travel.

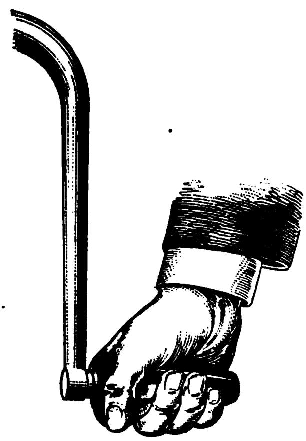
From the preceding it is evident that for a given rate of travel the spark can be farther advanced when the throttle is well closed than when it is open. One reason for this is that when the throttle is nearly closed and the charge entering the cylinder is consequently lighter in weight, the combustion of the charge is less rapid. Another reason is that there is a lower degree of compression in the case of the reduced charge. The rate of combustion is more rapid the higher the compression.

STARTING, RUNNING, AND STOPPING

5. Preliminary Precautions.—In the following discussion it is assumed that the car has been prepared for starting and has all the necessary supplies. First, set the speed-control levers so as to bring the change-speed gears into neutral position; in some cars this cannot be done until the clutch is released. In any case, put on the brakes after releasing clutch. This is generally done by means of the brake lever located at the side of the car. This brake lever is operated by hand and is provided with a pawl and ratchet

for locking it in position so as to hold the clutch out of engagement and the brakes set. If the car has no ratchet brake, or if it has one that is not in working condition, either have some one in the car hold the brake or block one or more of the wheels with large stones. Set the spark lever in the late, or retard, position and open the throttle half way or less (on some automobiles the throttle must be fully opened). Open the compression relief valves, if there are any, before cranking. Many cars—in fact, practically all large cars—are provided with such valves, and some are provided with a

(a)



(b)

Fig. 1

convenient method of opening and closing them. The relief valves should be closed as soon as the engine starts.

6. Cranking.—In cranking the engine, always take care to pull up on the hand crank during the part of its rotation through which there is the greatest resistance to its turning. It is preferable to learn to crank an engine with the left hand, standing with the left side turned a little toward the car. Because the left arm is seldom strong enough, the right arm is used by most drivers. In any case, grasp the handle so that the thumb is folded up against the fingers, as shown in Fig. 1 (*a*), and not around it, as shown in (*b*). Then a back

kick will do no harm, but will simply open the fingers. This is particularly true when the left hand is used in cranking, because then the operator's arm is extended upon the upward pull of the handle and the back fire will open the hand and throw it out of the field of rotation of the crank.

As soon as possible after the engine has started, close the throttle as much as possible without stopping the engine or making it work irregularly; never allow the engine to race any longer than absolutely necessary.

The cranking can be done slowly if a vibrator coil and battery are used for starting the engine; or it can be done with the magneto if the latter has a spring-operated rotating member that is first held stationary and then snaps around as the driving shaft is further rotated. If the engine fails to start on the combustible charges remaining in the cylinders, it will generally be necessary to crank somewhat rapidly, giving a quick pull on the crank so as to draw in a combustible mixture from the carbureter. Two or more pulls on the crank are generally required to get a fresh charge into one of the cylinders and ignite it.

When starting on a magneto having no provision for rapidly turning its rotating member at slow engine speed, the engine must be cranked at some given speed, say 30 revolutions per minute or so, in order to produce a spark for igniting the charge in the cylinder.

7. Priming the Carbureter.—The carbureter should be primed if the engine does not start with proper cranking. If there is no priming device on the carbureter, place one hand, a glove, or a cloth over the air intake of the carbureter so as to obstruct the air passage partly while cranking. To start in this manner may require the assistance of a second person.

Some carbureters are provided with stops for temporarily obstructing the air-inlet passage while cranking the motor. The obstruction of the air intake causes more suction at the gasoline nozzle, so that more gasoline is drawn out than when the air passage is free.

As soon as an explosion occurs, the engine will probably start to run faster than is desirable. This speed can be checked by closing the throttle somewhat more. If the engine is to run for some time while the car remains at rest, it is advisable to advance the spark somewhat and to close the throttle as far as possible without stopping the engine or causing it to run irregularly. It should be remembered that advancing the spark tends to increase the speed, and that a late spark tends to heat the engine.

8. **Running.**—It will be assumed that the car in question has a sliding-gear transmission, since there are more steps to the operation of this type of gear than to the planetary- or friction-gear drive; also, that a vibrator spark coil is used in the ignition system, because it requires more attention than a magneto ignition system.

After taking the driver's seat, first set the speed-control lever for slow speed forward and release all brakes. Immediately retard the ignition, open the throttle so as to give the engine more speed, and let the clutch into engagement gently. The throttle may be opened still farther as soon as the clutch begins to come into engagement and the car starts to move. The spark can be advanced and the throttle closed somewhat as the car gains speed.

If the speed of the engine becomes higher than is desirable for continuous running, the speed control can be shifted to second speed. To do this, the driver should first place his foot on the clutch pedal and grasp the speed-control lever. He should then throw the clutch out of engagement by foot-pressure and immediately shift the control lever. The clutch can then be let into engagement gently. The shifting of the control lever should be done quickly and unhesitatingly after releasing the clutch; delay is apt to be injurious to the change gears. If the change is made while climbing a grade, it is also necessary that the clutch be engaged quickly after shifting the gears. The whole process can be completed by an experienced driver in a fraction of a second. The spark should always be retarded before shifting from slow speed to

a higher speed. Until sufficient skill is attained in shifting the gears and reengaging the clutch quickly, it is also advisable to close the throttle partly while making the gear change. After becoming skilful, there is no need of disturbing the setting of the throttle. A shift to a still higher gear can be made in the same manner as just described.

9. A shift from any speed to a lower one is generally more difficult to make than a shift to a higher speed. This is chiefly because the speed of the driven member of the clutch must be increased during the change, the rate of travel of the car remaining about the same in the meantime. It requires considerable skill to follow rapidly the steps of the change, which are as follows: Release the clutch; shift the gears to neutral, engage the clutch, speed up the engine to give the clutch a speed equal to or somewhat higher than the speed it will have when the lower-speed gears are engaged; release the clutch, and immediately shift the gears. The clutch should then be engaged gently.

A change to lower gear is made probably more frequently when ascending a grade. If the throttle is not disturbed, the engine will speed up of its own accord as soon as the clutch is released, provided the throttle is set well open, as is ordinarily the case when climbing a hill. Under some conditions, but not with cars having an interlocking system between the clutch and change speed, it is possible to drop to a lower speed when going up hill without releasing the clutch, but this practice is likely to be dangerous to the change gears.

10. The engine should never be run at so slow a speed that each impulse can be felt as a jerk on the car. Its speed of rotation can be slower when the throttle is well closed than when the engine is working hard on an open throttle.

While it has been stated that the clutch should be engaged gently, this cannot always be done. Leather-faced cone clutches are especially given to sudden gripping and consequent jerking when they are let in. This gripping does not

generally occur when the clutch leather is new, but it is almost sure to occur with such clutches after the leather has become either glazed and slightly burned or somewhat oily. Multiple disk clutches do not generally seize and jerk when they are properly lubricated. However, it is generally difficult to keep them properly lubricated, as temperature changes may modify the condition of the lubricant to such an extent that the clutch will either not take hold quickly enough or will seize and jerk. However, some of the more modern clutches with special friction materials operate quite well if ordinary care is taken to keep them in proper condition.

If, in shifting, the change gears are not immediately brought into full engagement—lack of full engagement being generally indicated by a rasping noise caused by the ends of the teeth striking each other—they should immediately be moved entirely free from each other so as to prevent excessive injury to them. The safest procedure for the beginner in a case of this kind is to stop the car and again start it from rest; however, after some skill has been attained, it is generally possible to throw the gears into position for another speed than that which it was desired to obtain, and then to make a second attempt at shifting to the required speed.

To reverse the travel of the car, it must first be entirely stopped, after which the setting of the gears to the reverse position and the putting in of the clutch is a simple operation. To steer the car backwards, however, is not very easy, except at a very slow speed.

11. There are some conditions under which it may be both desirable and convenient to run the engine for a very short time on late spark and open throttle, thus securing a strong pull at a comparatively slow speed, but not slow enough to cause jerking. Such a condition exists when the car is either passing over a few rods of heavy road or traveling up a short grade, the remainder of the road being good or level. The heating of the engine during such a short interval is not great; at any rate, it is less objectionable than changing temporarily to a slow gear.

12. Stopping the Engine.—The engine can be stopped by opening the electric circuit, or switch, of the ignition system. This can be done either by removing a plug or operating a button provided for the purpose. If the throttle is opened just before the engine stops, each cylinder will be filled with a combustible charge when the engine stops. The throttle had better be closed after the engine stops and the spark is retarded. The engine is thus left in a condition for starting readily.

13. Starting an Engine on a Down Grade.—After a car has been stopped on a down grade, the engine may be started as follows: First, release the brakes—if the grade is not steep enough to start the car, the driver can give it a shove while stepping aboard—and then retard the spark to the usual starting position, set the gear on high or medium speed, close the ignition switch, and open the throttle somewhat. When the car has gained sufficient momentum, gradually let in the clutch, which will start the engine. Immediately after the engine is started, the position of the throttle, spark, and change-speed levers can be changed to suit road conditions. This method of starting an engine is a very convenient one if it is possible to select a down grade for stopping, as will often be found to be the case.

On a moderate down grade, small cars having planetary transmissions can be held stationary by stopping the engine and putting the gear on the low speed.

When a crank is lost or broken, the car can be started in the manner just mentioned. In case the car is not on a down grade, it must be pushed forwards until sufficient speed is obtained to start the engine.

14. Starting an Engine on Spark or Compression. When the usual form of four-cycle engine with four or more cylinders is stopped in the manner described in Art. **12,** the piston in one of the cylinders is in position to be started by the impulse of the charge in the cylinder as soon as the charge is ignited and burned. The charge can be ignited by

retarding the spark, provided the adjustment of the timer is of sufficient range to close the primary circuit when the piston is standing as far beyond its dead-center position as is usually the case when the crank-shaft comes to rest.

Many engines—and their number is increasing—are provided with separate starting switches or push buttons. By means of such a device, the primary circuit can be closed regardless of the position of the crank-shaft, and when a high-tension distributor is used, the spark—due to closing the primary circuit and the consequent action of the vibrator or spark coil—will occur in the proper cylinder for starting the engine in the right direction of rotation. In the case of an individual spark coil for each cylinder, this method of closing the primary circuit with a push button or a switch will produce a spark in each cylinder at the same instant. This would not be conducive to starting the engine.

A two-cylinder, four-cycle, opposed engine rarely stops in position to start by exploding a charge in it. A two-cycle, two-cylinder engine whose explosions occur at equal intervals tends to stop with a charge in each cylinder and one of the pistons in position to start the engine in the proper direction of rotation when the charge in the corresponding cylinder is exploded. In general, an engine that has more than four cylinders can be started on the spark within a reasonable time after stopping, provided it is of the usual form of construction found on automobiles. The more cylinders there are, the more likely is the engine to start on the spark.

15. Descending a Hill.—A very steep hill or grade can be descended with the greatest safety in the ordinary car by setting the change-speed gears on slow speed forward, turning off the ignition switch, and applying the brakes to such an extent as may be necessary. The driver may use the lowest gear for a long, steep hill, the second gear for a half-mile hill not so steep, and so on, closing the throttle and opening the ignition circuit in each case. If the speed threatens to increase while the third speed is in use, pass to the second in the manner indicated in Art. **9.** If the speed

does not decrease fast enough, brake lightly with the hand-brake or the foot-brake, provided the one used does not disengage the clutch. Some drivers advise doing away with any interlocking arrangement that causes disengagement of the clutch when the hand-brakes are applied, claiming that the interlocking system is an inconvenience.

16. When the change-speed gears are set on slow speed, there is greater frictional resistance to the travel of the car than when the gears are set on any other speed. In such cases, the car must of course be run slowly down the grade. For hills that are not excessively steep and especially when the car has a planetary transmission, it is usually sufficient to use the high-speed forward, with the ignition switch turned off, using the brakes as much as necessary.

Some engines are provided with means of opening small relief valves that connect with the compression chamber of each cylinder. It is said that the engine offers still more resistance to the travel of the car when these air valves are opened than when they are closed. Moreover, the forcing in and out of air tends to cool the cylinders and thus reduces the successive compression and rarefaction of whatever gases there may be in the cylinder, rarefaction tending to send the lubricating oil to the heads of the cylinders, where it may foul the spark plugs and valves.

On very long, gradual descents, it is usually advisable to use the engine as a brake, preferably by opening the relief valves as just explained. The change-speed gear can of course be set at any desired speed. The use of the engine in this manner helps to prevent excessive heating of the brakes, which would otherwise occur on very long descents. Some brakes are arranged so that they can be cooled by allowing water from a tank to flow on the brake shoe. As a matter of safety, the water should be applied before the brake has become exceedingly hot, unless the brake shoe and drum are made of steel or of some similar material that will not fracture when suddenly cooled, as when a stream of water strikes it.

17. Failure of Brakes While Descending a Hill.—If the brakes of a car fail while descending a hill at full speed, the best way to stop the car, according to J. D. Maxwell, is to withdraw the clutch first, next put the change gear on the second speed, then open the ignition circuit, and finally throw in the clutch very slowly and carefully. The car will then gently come to a standstill. In dropping into a lower speed, however, the engine should be speeded up to correspond with the speed of the car before throwing in the clutch. According to the same authority, it is best not to throw in the lowest gear, because this will give a sudden shock to the machinery and is liable to send some of the passengers against the front seat or over the dashboard; also, there is danger of stripping the gears.

18. Stoppage of Engine on Up Grade.—It may sometimes happen that the engine will stop running while ascending a steep hill. The natural procedure in such a case is to apply the brakes immediately, so as to prevent the car from running backwards. If the brakes are out of repair, or if they are not powerful enough to prevent the car from starting backwards under such conditions, the best thing that can be done is to set the change-speed gear in the reverse position at once and to turn off the ignition switch; also, if the engine is provided with small relief air valves that can be operated from the driver's seat, these valves should be opened. Unless one is very sure of the holding power of the brakes, as determined by a recent test, it is a good practice, if the engine stops, to throw the change-speed gear into reverse position immediately, without waiting to see whether the brakes will hold the car from running backwards, and in case the car is fitted with them, to lower the sprags or drop brakes. Whenever it is possible to do so the car should be guided to one side of the road in order to prevent it from running down hill. But if the roadway happens to be precipitous on both sides, or if it happens to be between deep or unsafe ditches, this cannot be done, and the car must at all hazards be held from running backwards. A good plan, therefore, is to practice

running a car backwards in order to be able to guide it, in case of necessity, at least so long as its speed can be kept down to a moderate rate. In steering a car backwards, the tendency is to turn the steering wheel too much one way or the other, thus causing the car to run into one side of the road.

19. Stopping for Repairs.—If repairs have to be made while on the road, the car should be stopped at one side of the traveled portion of the road, especially if it is in a locality where there is much traffic. If the car is in such a condition that it can be readily moved along the roadway, a good plan is to seek a place where the road is straight, thus obviating danger of being run into, and where repairs can be made with as great ease as possible. A shady place, out of the dust of the roadway, is extremely desirable on a hot day. Any reasonable amount of time consumed in getting a car into such a place will be more than regained by the increased facility with which the work can be done. If the repairs have to be made at night, care should be taken to see that lights are exposed at both the front and the rear of the car.

It is a good plan to spread a large piece of oilcloth or rubber sheeting, such as is used for storm aprons, under the portion of the car on which repairs are to be made. The cloth is not only more comfortable and cleaner to work on than the earth, but it will catch any parts that may happen to drop; besides, without the use of such a cloth, such parts, if oily, would generally become covered with dust and grit. The danger of losing small parts is also obviated by using a cloth in this manner.

When handling cotter pins in making roadside repairs, the points may be made to stay snugly together for reinsertion by slightly spreading them with the point of a knife blade inserted near the shank, and then pinching the points together with a pair of pliers. When the knife blade is removed the points will hug each other closely.

20. Starting a Cold Engine.—If a car has been standing in an unheated garage in winter, it is sometimes difficult

to start the engine because the gasoline will not readily vaporize at the low temperature. This is especially true if the gasoline is of a poor quality. Priming the cylinders by putting about a thimbleful of gasoline through the priming valve will sometimes be effective in starting. It is advisable to allow the engine to stand a minute or more after priming in this manner, in order to let the gasoline become partly vaporized.

A combustible mixture can sometimes be conveniently obtained in the engine cylinder by opening the relief valve of the combustion chamber and either priming the carbureter to excess or holding the hand over the carbureter air intake while cranking the motor. An overrich mixture is thus formed in the carbureter, and this mixture is then diluted in the cylinder by the air drawn in through the open relief valve during the suction stroke. As soon as a combustible mixture is obtained in the cylinder, as indicated by the flame spit out through the relief valve, the latter can be closed and the engine started by cranking in the usual manner. There should be an explosion the first time that a spark occurs after closing the relief valve. When cranking the engine slowly with the relief valve open, as just described, two or three explosions may sometimes occur in rapid succession in the same cylinder if a vibrator spark coil is used. This succession of explosions is doubtless due to the fact that the mixture in the cylinder is overrich and only partly burning during the first explosion. More air is then immediately drawn in through the open relief valve on account of the contraction of the cooling gases in the cylinder, so that another combustible mixture will be formed. This mixture is immediately ignited by the continued series of sparks at the plug, or possibly by the flame still lingering in the cylinder.

Another method of starting a cold engine is to warm the carbureter, and in case of extreme cold it is advisable to warm both the carbureter and the engine. Doubtless the safest way of warming is to pour hot water over the parts, taking care not to let any get into the carbureter, or to fill the water system with warm or hot water. This difficulty,

however, is not likely to occur with the more modern form of carbureters.

21. Effect of Altitude on the Power of an Engine. The power that an engine will develop decreases as the car climbs to a higher altitude, other factors remaining unchanged. This decrease of power at the higher altitude is due to the fact that less air is drawn into the cylinder during each charging stroke.

The air of the higher altitude is, of course, more rare than at sea level. The decrease of atmospheric pressure is, roughly, ½ pound for each 1,000 feet of altitude. The pressure at sea level is about 14.7 pounds per square inch. The decrease of pressure per 1,000 feet of altitude is therefore between 3 and 4 per cent. of the pressure at sea level. The decrease in power of the engine corresponds approximately to this decrease of atmospheric pressure. Therefore, at an altitude of 4,000 feet, the engine will develop about 87 per cent. of the power that it will give near sea level.

ADJUSTMENT, LUBRICATION, AND CARE OF VARIOUS PARTS

PREPARATIONS FOR A TRIP

22. General Inspection.—The preparations for a trip are, of course, not the same for all cars, owing to the difference in designing, the different methods of lubricating, etc., but the following will give a general idea of what should be done. The preparations mentioned are not intended to include the care of parts that require infrequent attention, such as spring connections, ball bearings, etc. The care of such parts as these will be taken up separately.

If the car is in good running condition, it should be prepared for a trip by filling the oil lubricators and grease cups, by putting grease in the timer, provided it is of the type that is packed with grease (some timers are lubricated with oil

from the lubricator), and by filling the fuel tank with gasoline. It will also be necessary to see that the cap, or plug, is tight on the compression lubricator and the compression fuel tank, provided these are used, and to make sure that the vent of a gravity fuel tank is open. The cap or plunger of each grease cup should be screwed down so as to force grease into the bearing, or the plunger should be set so that it will force in grease if the bearing becomes warm. The pueumatic tires should be inflated to the proper hardness.

It is never out of place to make an examination of the steering mechanism in order to see that nothing is loose; the same applies to the caps on the hubs of the road wheels. It is also advisable to see that all cotter pins are in place and in good condition.

If the contemplated run is to extend into darkness, see that the oil lamps are filled and trimmed; also, that the gas generator is supplied with carbide and water, or that the pressure gauge on the gas storage tank shows sufficient pressure to indicate that there is enough gas in the tank for the run. If the engine is cooled by water, see that the water system is full of water and that there is no leak in packed joints, pumps, nor any other place.

23. Inspection of Water System.—After filling a cooling-water system that has been almost empty, it is advisable to run the engine a short time to determine whether or not the radiator warms up in a manner to indicate proper circulation. An air lock sometimes prevents proper circulation of the cooling water just after the tank has been filled. Some cooling systems are provided with vents that can be opened to allow the water to escape. One of these vents is not infrequently placed near the circulating pump. In a well-designed cooling-water system there is little or no probability that an air lock of the nature just described will occur.

24. Inspection of Gasoline System.—An air lock sometimes occurs in the connections between the fuel tank and the carbureter after the fuel system has been drained and when a new supply of gasoline is put in the tank. This

air lock is sometimes, but not often, due to stoppage of the air vent above the gasoline in the float chamber of the carbureter. More frequently, however, it is due to the more or less vertical bends, or stretches, in the pipe that connects the carbureter to the fuel tank. Such an air lock will sometimes disappear of its own accord if the engine is started and has enough gasoline available in the float tank to keep it running for a short time. The vibration of the engine seems to get rid of the air. In other cases, however, the air lock may be removed by draining the carbureter. Probably the quickest and most efficient way is to place one's mouth tight against the opening through which the fuel tank is filled, and then blow into the tank to create as great a pressure as possible above the gasoline. Evidently, some method of connecting an air pump to the fuel tank will suggest itself, but such an arrangement is more elaborate than is ordinarily necessary.

The sticking, binding, or leaking of the check-valve in the pipe leading from the engine exhaust to the gasoline tank in a compression-feed fuel-supply system will, of course, reduce the pressure in the fuel tank, and there will consequently be no fuel forced to the carbureter. The breaking or the weakening of the check-valve spring will have the same effect.

25. Straining of Gasoline.—It is generally advisable to strain the gasoline when filling the fuel tank. The straining can be done through a chamois skin, a felt cloth, or any woven fabric that has a close mesh, such as muslin or linen goods. It is best not to use anything that is likely to give off lint, because the small orifices through which the gasoline must pass are certain to become clogged ultimately if lint is carried in with the gasoline. Although it is always wise to strain the gasoline, if the fuel system has a strainer in it, there is, of course, not so much need for straining, especially if the permanent strainer can be readily removed for cleaning and it is not probable that there is any water in the gasoline. Fuel systems are usually provided with a wire-gauze strainer in or near the carbureter.

Chamois skin will not allow water to flow through it after it has been moistened with the gasoline; neither will a closely woven cloth or felt after the fabric is wet with gasoline. On the other hand, gasoline will not flow through a chamois skin, or even a closely woven fabric, when the strainer is wet with water.

A convenient method of using a strainer is to put it in the funnel through which the gasoline is poured into the tank. Two-piece funnels made so as to hold the strainer between the two parts are convenient to use. If the strainer becomes fouled so as not to allow the gasoline to pass through freely, it can be washed in either water or gasoline. If water is used for washing, the strainer must be thoroughly dried before it is used. Chamois skin, on account of its close texture, is more apt to become fouled than a woven fabric, and thus retard or prevent the flow of gasoline.

ADJUSTING THE CARBURETER

26. The construction of a carbureter controls to a considerable extent the method to be used in adjusting it. The steps necessary to adjust a carbureter having an automatic auxiliary air valve that regulates the amount of air flowing past the spray nozzle cover practically all adjustments necessary in any ordinary type of carbureter.

Before attempting to adjust the carbureter with the engine in operation, it is well to make sure that when the engine is started the spark will not occur before the crank is past its dead-center position. This can be done safely by first closing the spray nozzle of the carbureter and cranking the engine very slowly by hand until the position of the hand crank or flywheel corresponding to the time at which the compressed air in the engine cylinder begins to drive the piston outwards is determined. Then, with the switch closed, the crank-shaft should be turned very slowly and the position of the crank-shaft at which the spark occurs should be noted. The spark control should be set in position for the latest spark during this test, and the spark should occur at about the

instant that the compressed air begins to force out the piston. No satisfactory adjustment of the carbureter can be made until each cylinder is tested in this manner to determine whether the spark is correctly timed. The extent of sparking can be noted by the vibration of the trembler of the induction coil, provided a trembler is used, or by disconnecting the wires from the spark plugs and placing the terminal of each wire within $\frac{1}{8}$ inch or so from the metal of the plug or of the engine. The spark will then be visible, and in a quiet locality, it will also be audible.

27. Adjusting Carbureter in Garage.—The method of adjusting a spray-nozzle carbureter with auxiliary air valve is as follows, assuming that the carbureter is completely out of adjustment:

Set the automatic air-valve spring at about midway between the extremes of its adjustments. Open the valve between the fuel tank and the carbureter, and open the spray-nozzle valve an eighth of a turn, or so. Prime the carbureter until the gasoline drips from it, if it is of such a form that surplus gasoline flowing from the spray nozzle runs readily from the carbureter. If the carbureter is of a type that retains the overflow from the spray nozzle, note whether the float chamber of the carbureter fills promptly after the fuel-tank valve is opened. Set the spark lever in late position, and then crank the engine.

If the engine makes only a few revolutions and stops, then open the needle valve slightly more, prime the carbureter, and crank the engine again. Continue these operations with different settings, more open or more closed, of the needle valve of the spray nozzle until the engine makes several revolutions after starting. Note whether sooty smoke comes from the exhaust. If it does, then the mixture is too rich. The black smoke of the exhaust should not be confused with the blue or bluish-white smoke that arises from too much lubricating oil in the engine cylinder. The blue smoke hangs in the air, but the black smoke is generally visible only as it escapes from the exhaust pipe, or muffler. Close the needle

valve accordingly, a little at a time, until the black smoke disappears.

28. The engine should be allowed to run a little while after each adjustment of the needle valve, in order to allow it to come to a constant condition of operation. There may be explosions in the muffler during the time that black smoke is coming from the exhaust. An overrich mixture often fails to ignite. The unburned mixture then passes out with the gases, and in mixing with air in the muffler, becomes a combustible mixture that may be ignited by the next exhaust of a burning charge, thus causing an explosion in the muffler. Muffler explosions also occur on account of a faulty ignition system. They are generally quite heavy and loud.

Again, if the engine continues to run, but there is back firing into the intake pipe and carbureter, then the mixture is too lean. The explosions in the intake due to back firing are not so loud as those in the exhaust and muffler. In case of carbureter explosions, open the needle valve of the carbureter gradually until back firing stops.

Next, close the throttle until the engine runs slowly, and then open it quickly to see whether the engine responds to the open throttle by increasing speed promptly. If the engine back fires when the throttle is opened, thus indicating a lean mixture, the air-valve spring should be tightened so as to press harder on the automatic valve; but if black smoke appears when the throttle is opened, the air-valve spring should be set for less pressure.

Tightening the air-valve spring gives a mixture that is proportionately richer on open throttle; relieving the spring tends to make a mixture that is richer when the throttle is only slightly opened.

29. Adjusting Carbureter on Road.—The next step is to try the car on the road. This can generally be done most satisfactorily on a slightly ascending grade; but the rate at which the car speeds up on the level road is also a means of testing the adjustment of the carbureter. In making the adjustments on the road, the same general method already

given for the preliminary test can be followed. In general, it will be found that the adjustment can be made quickest by giving the air valve different settings and then testing the needle valve throughout the range that appears necessary to obtain the best power without changing the setting of the air valve. The air valve can then be adjusted again, and the same process repeated with regard to the needle valve.

It should be borne in mind that the setting of the carbureter that gives the best results in a garage where the temperature is approximately that of a living room, and the engine is running light, that is, without load, will not generally be the best when the car is taken out on the road, especially if the outdoor temperature is greatly different from that in the garage. To a less marked extent the adjustment of the carbureter is affected by differences of moisture in the air in the garage and that outside. The travel of the car may also affect the mixture.

LUBRICATOR AND LUBRICATING OIL

30. Straining of Lubricating Oil.—Lubricating oil not infrequently contains chips of wood, grit, or other foreign matter that may injure the parts on which it is used, or stop the passages of the lubricators. Such foreign matter can be removed by straining the oil through wire gauze of sufficiently fine mesh. A piece of the gauze soldered near the lower part of the top of a funnel is convenient for this purpose. A small basket strainer, such is is used on teapots, is also convenient when it can be readily attached to the can or pot from which the oil is poured. The mesh should be finer than is generally used for tea, however.

31. Adjustment of Lubricator.—The lubricator of an engine that has no circulating system of lubrication requires careful adjustment. Such a lubricator ordinarily has connections with the main bearings of the engine, and in addition there is often one or more connections leading to the crank-case. A gravity or a compression lubricator should always be adjusted while the engine is running.

Just what the rate of feed to each part of the engine shall be is hardly possible to designate in a general statement; but for the crank-shaft 2 to 4 drops a minute at each sight feed is generally enough for an engine of any ordinary size after it has been used long enough to get the running parts in good working order. This statement applies to a crank-shaft that has plain journal bearings. For ball bearings, the quantity of oil required is very small, and as a rule there is no pipe leading to such bearings from the lubricator. Ball and roller bearings are generally packed in grease when put together, and this grease usually lasts a long time.

In a vertical-cylinder engine whose piston and wristpin are lubricated by the splash system, the adjustment of the lubricator naturally must be such as to retain a proper level of oil in the crank-case. It is always safe to say that the engine is not getting too much oil in the cylinders if it does not show blue or bluish-white smoke in the exhaust. Therefore, a safe method of adjusting the lubricator is first to allow it to deliver oil at a rate that will cause a slight showing of blue smoke in the exhaust, and then to cut down gradually the rate of feed of oil until the smoke disappears. For an engine that develops a medium amount of power, 6 or 8 drops of oil per minute per cylinder at the sight feed will generally be enough for proper lubrication. Engines can of course be run on a smaller quantity of oil, but the amount of power developed per cylinder will generally not be so great as the power that can be obtained by more copious lubrication within the smoke limit.

32. In some horizontal engines that are lubricated by the customary method of applying oil to the upper side of the piston through an oil hole in the cylinder wall, more oil is required for one cylinder than for the other. The reason for this is that the crank-shaft and connecting-rods tend to throw more oil into the cylinder toward which the crankpins move during the part of their rotation that brings them nearest the bottom of the crank-case. This is especially true if the crank-case is tight enough to hold oil, so that there will be a splash

action when the rotating parts strike the pool of oil. The main bearings of a horizontal engine will generally require more oil than those of a vertical splash-oiled engine of the same size.

33. A fact to be remembered is that when the oil is cool, as when the engine has been standing overnight in a garage that is not warmed, it will not flow so freely from a non-mechanical-feed type of lubricator as when the oil is warmed up later in the day. The lubricator must either be readjusted when starting out in the morning or the engine must be run slowly until the flow of oil is normal, the latter method being preferable; otherwise, the engine may be injured on account of lack of oil.

BRAKES AND FRICTION CLUTCHES

34. Brakes.—As a matter of safety, it is exceedingly important to have the brakes on a car powerful and in perfect working order. Each set of brakes should be powerful enough to bring the car to a gradual stop on a good level road when the engine is pulling to its full capacity on low-speed gear. Each set should also be equally effective in resisting backward travel of the car. This is necessary in order to insure that the car will be held from running backwards in case it is stopped on a grade as steep as the car can climb at slow speed. Some brakes hold well to resist forward travel, but not to prevent backward travel. Care should be taken to see that the rubbing surfaces of the brakes are not so worn that, after only slight additional wear, they cannot be adjusted to hold to their full capacity.

When not applied, a brake should not drag, as dragging will cause loss of power and will also heat the brake. This heating, in some cases of excessive dragging, is sufficient to burn the non-metallic part, so as to char it and to blacken or burn off the paint on the brake drum. Brakes should be frequently inspected and tested, especially before making a long trip, to determine whether or not they are in good condition.

35. Leather-Faced Cone Clutches.—If the leather of a leather-faced cone clutch is kept free from oil, it is liable to become glazed and burned so as not to hold well. On the other hand, if oil from the machinery reaches the leather, the leather loses its gripping quality to some extent and becomes uncertain in its action. One of the remedies for a slipping leather-faced clutch is to tighten the closing spring, or other closing device, so as to press the friction surfaces together with more force. Another remedy is to put something on the friction surfaces that will increase their frictional action without causing them to seize and jerk suddenly. Some cone clutches can be readily adjusted on the road, but many designs are of such a form that adjustment is a long and tedious operation.

Powdered chalk or fullers' earth will temporarily improve the action of a leather-faced clutch if placed between the friction surfaces when the leather is either charred or oily. Either of these substances can be obtained at drug stores. They can be put into the clutch while it is held disengaged either by simply throwing them in or by blowing them in through a piece of tubing. Rubber tubing also can generally be purchased at drug stores.

36. When there is more time available than is usually the case on the road, a slipping or a gripping leather-faced clutch can be put in good condition by washing out the clutch with gasoline and then applying a small quantity of either castor oil or neatsfoot oil, or equal parts of glycerine and castor oil. The washing can sometimes be done without taking the clutch apart. In such a case, a liberal quantity of gasoline should be put into the clutch, and the clutch then rotated slowly to bring the gasoline into contact with all parts of the leather. After continuing this process for several minutes, the clutch should be opened and allowed to stand open for ½ hour or more to allow the gasoline to vaporize. A couple of teaspoonfuls of either castor or neatsfoot oil or of equal parts of glycerine and castor oil can then be put on the leather. Lubricating oil should never be used on the

leather. The oil can be distributed over the leather by closing the clutch so that the friction surfaces press very lightly against each other, and then rotating one of the members of the clutch so that the friction surfaces rub over each other. Opening the clutch frequently during the rotation will aid in distributing the oil. After the oil is thoroughly distributed, the clutch should be left standing in the release position for several hours, as overnight. It will then be ready for service.

If the clutch is of such a form that the gasoline and oil cannot be readily applied while it is assembled, the only means of cleaning off the machine oil and applying the oil dressing is to take the clutch apart. If the leather is glazed to any extent, the action of the clutch can be further improved by roughening the leather with a coarse file after cleaning with gasoline. The oil dressing can be rubbed on while the clutch is apart.

Charred and glazed leather on a clutch generally cannot be remedied to any great extent. Roughening with a file and dressing with either neatsfoot or castor oil will ordinarily do more good than anything else. The obvious remedy is a new leather. Roughening the metal surface against which the leather rubs is sometimes recommended to make the clutch hold better. This is an extremely doubtful remedy, however. If the metal is roughened enough to grip the leather, it will tear small particles from the leather and thus cause its rapid destruction. If not rough enough to do this, the holding capacity will not be appreciably increased.

37. Multidisk, Metal-to-Metal Clutches.—The successful operation of multidisk clutches having metal-to-metal friction members depends to a great extent on the kind of lubricant that is used and the thoroughness with which the lubricant reaches all the friction surfaces. Usually, the most suitable lubricant is one that is quite thin and does not greatly change its condition in this respect with changes of temperature. Temperature changes are caused both by the heating of the clutch on account of its slipping in regular service and by changes in the weather.

If the clutch is adjusted to operate as near properly as possible when cold, it will generally act too suddenly when it becomes warm. On the other hand, if the clutch is adjusted for hot weather or a heated condition, it will not act properly on a cold day until it is warmed up by its own slipping. The clutch grips quicker when the oil is thin than when it is thick.

38. The lubricant that seems to give the best satisfaction for most metal-to-metal, multidisk friction clutches consists of a mixture of thin lubricating oil and kerosene. Either ordinary machinery oil or gas-engine cylinder oil mixed with kerosene is extensively used. The relative proportions of oil and kerosene depend on both the thickness of the oil and the design of the clutch. A thinner mixture is generally required for a clutch having broad friction surfaces than for one in which the friction rings are narrow radially. A suitable lubricating mixture is seldom if ever more than half kerosene.

Flake graphite is sometimes mixed with the lubricating oil for clutches. Its use, however, is generally not satisfactory for this purpose, chiefly because it cannot be kept on the friction surfaces. It is thrown outwards to the casing and remains there, especially in clutches that are not enclosed in a stationary casing.

If the lubricant leaks out so as to leave the clutch partly dry, it is almost certain that the clutch will suddenly seize and jerk when closed. Rather careful attention is necessary to keep the clutch properly lubricated and in working order. This is especially true when the clutch is not enclosed in a stationary case, such as an extension of the change-speed gear-case or of the crank-case of the engine. Both gear-case and crank-case should occasionally be washed out with kerosene.

39. Cork-Insert Clutches.—The use of cork inserts in either a cone clutch or a multidisk clutch gives a smooth action when closing the clutch as long as the inserts are in good condition. The cork is subject to burning and wearing away, especially in heavy service. When worn down,

the cork, of course, fails to act in the proper manner, and the consequent behavior of the clutch depends on how it operates in the absence of the cork. New inserts can be put in, but this involves taking the clutch apart, which is sometimes a long and tedious operation.

40. Miscellaneous Forms and Materials for Clutches.—As in the case of brakes, other materials, such as camel's-hair fabric, cotton fabric, vulcanized wood fiber, etc., are used for the friction parts of clutches. The behavior of these materials is practically the same as has been stated for cone and multidisk clutches, and the same care should be taken in operating them.

41. Planetary-Gear Clutches and Brake Bands. Planetary change-speed gears are ordinarily provided with two or more constricting bands and a friction clutch. The bands act in the same manner as contracting hand-brakes and require the same attention. The clutch is generally of the disk type, with a small number of pairs of friction surfaces. Ordinarily, it does not require such careful attention as a clutch used in connection with a sliding-gear change-speed transmission.

LUBRICATION OF VARIOUS PARTS

42. Sliding Change-Speed Gears.—In a well-made gear-case properly designed for retaining oil, ordinary machinery oil will give the best results. Engine cylinder oil can be used equally well, but it is more expensive. A heavy, or thick, oil is used in many gear-cases, especially those of earlier design, and in some gear-cases, even a jelly-like grease is used. Heavy oil or thin grease does not lubricate plain journal bearings well; they are apt to become dry and to cut, or abrade, even when there is a good supply of this lubricant in the case.

Flake graphite mixed with thin oil is an excellent lubricant, but the graphite has a tendency to settle in the oil grooves and corners of the gear-case. The oil grooves should, there-

fore, be made so as to allow free circulation of the lubricant, and the gear-case should be of such a form that the motion of the gears will keep the graphite, as well as the oil, in circulation. When the differential gears are located in the same case as the change-speed gears, as is the case when a pair of side chains is used for driving the traction road wheels, the same lubricant that is used on the change-speed gears is, of course, used on the differential gears.

43. **Planetary Change-Speed Gears.**—The construction of planetary gears is such that it is generally necessary to use either thick oil or a thin grease for lubricating them, provided they are not enclosed in a stationary case. The reason for this is that the more fluid oil, if used, would soon leak out. When the gears are enclosed in a sufficiently tight stationary case, a thin oil can be used.

44. **Differential Gears on Rear Axle.**— Practice shows that a thin oil is used to a great extent on the differential gears when they are located on the axle that carries the traction wheels, which is almost always the rear axle. About the only leakage that ever occurs from the differential casing is that which takes place through the stationary tubular part of the axle. Leakage in this manner is extremely objectionable, however, because the oil is almost certain to get on the brake drums and shoes and to drip on the inner side of the tires. Oil is very injurious to rubber tires. The oil leakage through the axle tube generally occurs when the car is running along the side of a sharply crowned road, or while turning a curve rapidly. It also occurs when the car is left standing on the side of a crowned roadway, especially just after a fresh supply of oil has been put in the case.

In a new, well-made car, the oil-retaining rings of felt, leather, etc. will generally prevent the oil from leaking out to any great extent, but as these rings become old and worn, there is generally considerable leakage if thin oil is used. A heavy oil or a jelly grease should be used if the thin oil leaks out on the brakes or tires. A mixture of graphite

and oil or thin grease is an excellent lubricant for a differential.

The bearings between the live axle and the stationary outer tube of an axle drive can be lubricated either with oil or with a jelly grease, according to the effectiveness of the tube in retaining the lubricant.

45. Wheel Bearings.—Ball and roller bearings are almost universally used in the wheels of automobiles. When used in this location, the most suitable lubricant for either form of bearing is a grease of about the consistency of vaseline when at the temperature of a living room. A grease of this quality will not work out of a wheel bearing that is properly protected by dust caps or washers of felt. A thicker grease is liable to become packed in the hub and on the axle so that it will not get on the balls or the rollers.

46. Transmission Chain.—When in constant use, the transmission chains that drive the traction wheels should be lubricated daily, although a chain will run a long time without any lubricant whatever. There is always some danger that an unlubricated chain will bind and seize at a pin and twist the pin off; this is especially true if the chain is new and its parts are not well fitted together.

A rather thin grease is suitable for the chain. It is best to put the grease on the inner side of the stretches of the chain. Both oil and grease are put on at the same time by some operators. Some cars are provided with an oil tube for constantly lubricating the transmission chain while it is operating. This tube is connected to the same lubricator that is used for the parts enclosed in the crank-case, and has a sight feed and adjusting valve. Only a very small quantity of oil is required for the chain.

Unless a chain is in extremely bad condition, its removal from the car for cleaning and lubricating may not be worth while. After removal from the car, the chain can be cleaned by immersing it in gasoline. The chain should be moved about considerably in the gasoline by taking hold of the ends and then raising one end while lowering the other. This

motion tends to work out the dirt from between the pins and links. After cleaning, the chain can be lubricated by first immersing it in rather heavy oil and then putting grease on it. Graphite grease is very satisfactory for this purpose. After thoroughly cleaning a chain, an excellent plan is to immerse it in a pan of hot tallow and then move it around so that the melted tallow will penetrate between the parts. It should then be hung up and the surplus tallow allowed to drip off.

47. Generally, a chain is made so that the links can be readily separated at one place in order to remove it from the car. A common method is to have a removable pin that is retained in place by a cotter pin (split pin) that passes through a hole drilled across the end of the pin. Other devices are also used.

The device illustrated in Fig. 2 is convenient for holding the links of a chain together while disconnecting or connecting them. The two hooks at the extreme ends are hooked into the links of the chain, and the ends of the chain are drawn

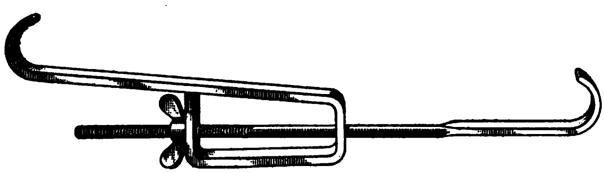


Fig. 2

together by turning the wing nut on the threaded end of the longer rod. It is not generally necessary to use such a device, however, if one of the sprocket wheels on which the chain runs is readily accessible. When this is the case, each end of the chain can be wrapped partly around the sprocket wheel, and the teeth of the wheel will hold the chain in place while the connecting pin is being replaced.

48. Universal Joints.—The universal joints on the propeller shaft that connects the change-speed gears to the rear-axle differential should either be oiled frequently if not

enclosed, or packed in thin grease if enclosed in a casing. A joint that is not enclosed is difficult to keep lubricated satisfactorily, and, besides, is subject to rapid wear on account of the dust and grit that reaches it. The tendency of a universal joint to wear is proportional, in a measure, to the angle between the two shafts that it connects. If the shafts are nearly in line, there will not be much wear; but if the angle is large, the wear will be rapid unless the joint is kept well lubricated.

The joints in the shaft connecting the friction clutch tc the change-speed gears also require lubrication, but the parts of the shaft are generally so nearly in line that there is little rubbing action in the joint, and consequently there is no great tendency to wear.

49. Steering Gear.—The mechanism usually found at the lower end of the steering column in heavy- and medium-weight cars, and to a considerable extent in light-weight cars, is generally enclosed in a case. Ordinarily, the best method of lubricating this part is to pack the case full of grease that is as thin as can be used without leaking out rapidly.

The swivel pins at the knuckles of the steering wheels are generally provided with grease or oil cups. The lubricant used in these cups should generally be rather heavy, or stiff, so that it will not readily drop from the pin bearings. If the pins are provided with dust rings, or washers, a thinner grease can, of course, be used than if there is no such protection.

50. Springs.—If a spring made up of a number of leaves, such as those used to carry the weight of the parts above the axles of the car, is not lubricated, it will not infrequently announce the fact by creaking. The remedy is, of course, to lubricate it. A lubricant, on the other hand, is injurious to the paint on the spring, unless it is a dry one, such as graphite. A dry lubricant, or even a stiff grease, cannot be readily introduced between the leaves of the spring. Jacking up the body of the car so that the wheels hang by the springs, facilitates lubricating. The operator, however,

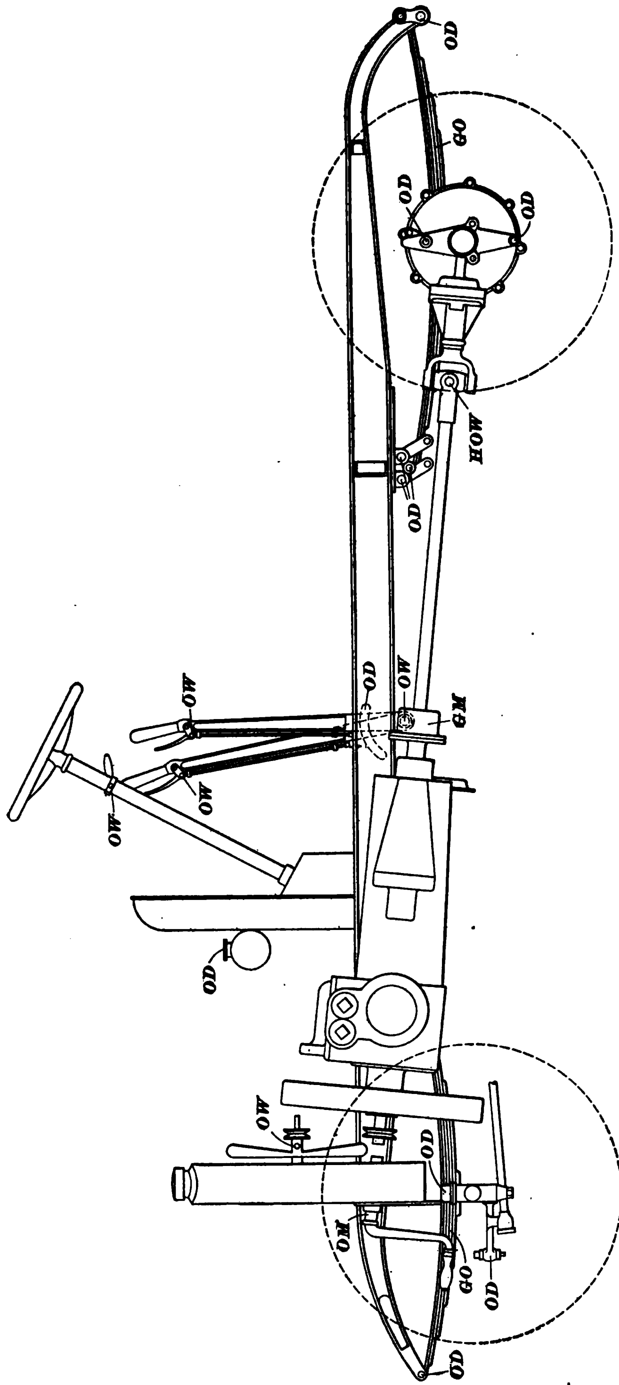


Fig. 3

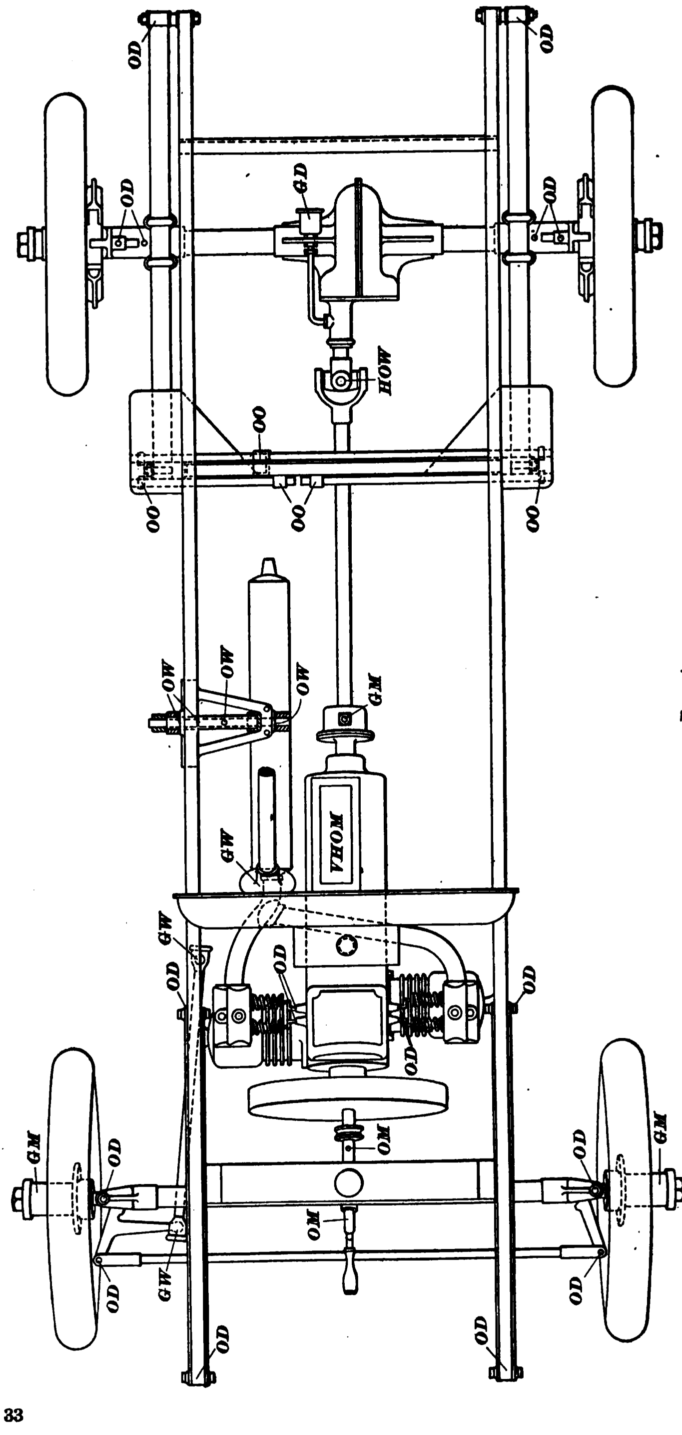


Fig. 4

is usually left to his own judgment as to whether he will use the easily applied oil with the consequent injurious action on the paint, or take more time and care, as required for putting on grease or graphite. The paint should always be wiped clean after applying oil or grease.

51. Additional Parts Requiring Lubrication.—All the parts that rub over each other must be lubricated if it is desired to operate a car in the most satisfactory manner. It has already been stated that the thinnest lubricant that can be retained between the rubbing surfaces is the most satisfactory. For minor parts, whose lubrication with grease would be difficult, the easily applied oil will answer well if put on frequently.

52. Lubricating Charts.—The diagrammatic lubricating charts shown in Figs. 3 and 4 represent the recommendations of one manufacturer relative to one type of the cars made by him. The car in question has been on the market for a long time and many of them are in use. The key to the letters used is as follows:

OD—Oil daily	*VHOM*—Very heavy oil monthly
OW—Oil weekly	*GD*—Grease daily
HOW—Heavy oil weekly	*GW*—Grease weekly
OM—Oil monthly	*GM*—Grease monthly
OO—Oil occasionally	*GO*—Grease occasionally

53. Admittedly the greatest obstacle to securing the possibilities of efficiency and long life, which are latent in almost every automobile, is the indifference and neglect of the operator. This neglect has its most immediate and far-reaching influence when it affects the lubrication. Few drivers are so criminally careless as to forget to replenish the mechanical oiler and crank-case supply, and most of them refill the gear-box and the rear-axle casing occasionally; but the many small oil holes and grease cups, which of necessity must be scattered over the chassis, are too frequently neglected. As a reminder to owners and chauffeurs of their duty in this

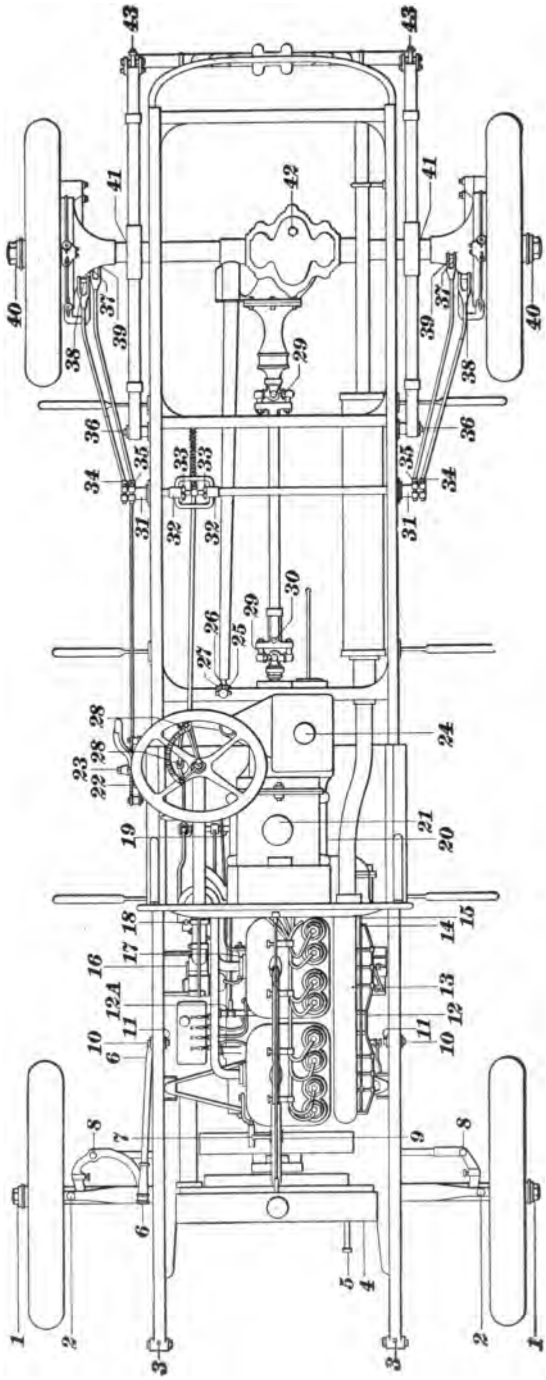

1 2 3 4 5 6 7 8 9 10 11 12 12A 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43

FIG. 5

TABLE I

INTERVALS AT WHICH PARTS OF AN AUTOMOBILE REQUIRE ATTENTION

No.	Parts	Lubrication	Give Attention	Miles	Number of Places on Chassis
1	Front hubs.........	Grease		1,000	2
2	Steering knuckles...	Grease		200	2
3	Springs............	Oil	Every day		2
4	Carbureter primer..:	Oil	Every day		1
5	Starting handle.....	Oil	Every day		1
6	Steering rod........	Oil	Every day		2
7	Fan support........	Oil		300	1
8	Tie-rod.............	Grease		200	2
9	Fan bearings........	Grease	Every day		1
10	Springs............	Oil	Every day		2
11	Springs............	Oil	Every day		2
12	Valve tappets.......	Oil	Every day		8
12A	Rocker-shaft........	Oil		300	4
13	Magneto...........	Oil (light)		500	2
14	Magneto connection.	Oil	Every day		1
15	Magneto bearings...	Grease		200	1
16	Steering post.......	Grease		750	1
17	Timer..............	Oil	Every day		1
18	Steering post.......	Oil		200	1
19	Clutch bearing and brake pedal.......	Oil		200	2
20	Clutch bearing......	Oil		200	1
21	Clutch ring.........	Oil		500	1
22	Gear-shift lever.....	Oil	Every day		1
23	Emergency brake lever............	Oil	Every day		1
24	Transmission.....	Oil (heavy, 1 inch deep in case)			
25	Torsion-rod spring..	Oil		300	1
26	Torsion-rod bearings	Grease		300	1
27	Torsion-rod bearings	Grease		300	1
28	Ball joints..........	Oil		200	2
29	Universal joints.....	Grease		250	2
30	Sliding joint (universal).............	Grease		250	1
31	Brake bearings......	Oil		200	2

TABLE I—(*Continued*)

No.	Parts	Lubrication	Give Attention	Miles	Number of Places on Chassis
32	Brake rods.........	Grease		300	2
33	Brake equalizer.....	Oil		300	2
34	Brake-rod ends.....	Oil		200	2
35	Brake-rod ends.....	Oil		200	2
36	Springs............	Oil		200	2
37	Brake-arm bearings.	Grease		200	2
38	Brake-rod arm ends (upper and lower).	Oil		200	4
39	Brake-rod ends.....	Oil		200	2
40	Rear hubs..........	Grease		1,000	2
41	Spring seats........	Grease		200	2
42	Rear axle........	Oil (heavy) to overflow		750	1
43	Springs............	Oil	Every day		2

respect, the Stevens-Duryea Company has included in its instruction book a double-page plan view of a chassis, which is reproduced in Fig. 5, with all oil holes and grease cups indicated by arrows and reference numbers. Table I shows the intervals at which each should be given attention. The illustration is so clear that further explanation seems unnecessary.

54. Use of Sawdust Grease.—It is sometimes considered desirable that, whatever the other conditions may be, the gears of a car shall run quietly. To meet this demand, there is found on the market a mixture of sawdust and grease intended for use in gear-cases. The sawdust has both a preventive and a deadening effect on the noise of the gears. As a lubricant, the mixture is of little value. Its chief use is for "doctoring" a worn car that is to be demonstrated to a prospective purchaser.

CARE OF LIGHTS

55. Gas Lights.—When filling an acetylene generator with fresh calcium carbide in lumps, the holder, or basket, should not be completely filled, unless there is space outside of it into which the ash of the carbide can fall after having passed through the chemical change brought about by the addition of water. The carbide swells during the chemical change, so that the volume of the resulting ash is greater than that of the carbide. The mesh of the wire basket into which the carbide is placed must be coarse if it is intended to allow the ash to fall through it during the process of gas generation. If there is no extra space into which the ash can fall, and if the carbide basket is not of very open mesh, the carbide receptacle should not be filled more than about two-thirds full. Generators designed for the use of solid blocks, or cartridges, of carbide are made with suitable space for the expansion of the carbide by the action of the water.

Partly used lump carbide cannot generally be depended on to produce good gas after the generator has been standing idle for some time after the charge of carbide is partly used. It is generally advisable to throw away the partly used carbide and to put in a fresh charge. The generators using solid cartridges of carbide are generally made so that the cartridges are moistened from the bottom, and are of such composition that the moisture does not creep up rapidly through them. The upper portion of a partly used cartridge is therefore good for use at a later time.

56. When filling the water reservoir of the generator, it should be made certain that the air vent above the water is open. If this vent is closed, the water will not continue to run freely to the carbide and the lights will gradually decrease in brilliancy. Also, if the water valve is opened up so as to allow an excess of water to run on the carbide at first, the rapid generation of gas will cause an excessively high pressure in the generator, because the gas cannot escape through the air vent above the water. This of course could not occur in

a generator provided with a valve or a water seal, which is acted upon in such a manner by an unusually high pressure of gas in a generator as to prevent flow of water on the carbide.

57. If the generator or the piping is not provided with a small trap into which the moisture from the generator can flow and remain, the gas lights are likely to flicker on account of the moisture passing out through the burner tips. These water traps do not generally require a capacity greater than a tablespoonful, and it is not customary to provide any means of draining them. The moisture that collects in a trap seems to vaporize and pass out with the gas when the generator is producing a comparatively dry gas.

The burner tips of acetylene-gas lamps frequently become clogged in the orifice with a deposit of carbon. This carbon deposit can generally be removed by means of a needle or a piece of fine wire; or, a small drill, if properly handled, may be more suitable. Care must always be taken not to break the tip.

58. Oil Lights.—Kerosene is usually burned in the oil lamps used on automobiles. The care to be observed in handling them is the same as that for any kerosene lamp. It is important that the light be fully extinguished when leaving the car in the garage. The wicks should be turned down from $\frac{1}{4}$ to $\frac{1}{2}$ inch after the light is out. Turning the wicks down in this manner reduces the amount of kerosene that gradually creeps up and distributes itself over the lower part of the lamp when it is left standing unlighted. It should be noted with certainty that the flame is extinguished before the wick is finally left turned down. If there is any flame there is possible danger that the lamp may explode. Explosions from this cause are not frequent, but it is always well to be on the safe side.

59. Electric Lights.— Incandescent electric lamps are taking the place of kerosene side and tail lamps as well as acetylene lamps. For automobiles, tungsten-filament lamps are much superior to carbon-filament lamps, as they require

a trifle less than one-half the electric energy and are in other respects fully as good. It is convenient to have a simple switch to control the two side lamps and the one tail-lamp, and it is well also to have located on the dash an extra lamp that is connected in series with the tail-lamp. This extra lamp, when lighted, will assure the driver that the rear light is also burning, and it can, moreover, be generally utilized to light some device, such as a speedometer. When two lamps are connected in series in this manner, care must be taken that each lamp requires exactly the same current for its proper illumination, each lamp requiring one-half the voltage of a single lamp that would be connected directly across the same battery circuit.

The electricity for the electric lamps may be obtained, preferably, from a storage battery or from a low-tension magneto generator. Care should be taken that the voltage at the lamps never exceeds that for which the lamps are made; otherwise, the lamps may be burned out, or at least have their useful life considerably shortened. Electric lamps require no care, except that the glass bulb be kept clean on the outside. When they burn out or are broken, they must be replaced with new lamps. This is a very simple matter, aside from the cost of a new lamp, for each bulb is provided with a screw base that can be readily screwed into a suitable socket inside the body of the lamp. When electricity is used for lighting it is very convenient to have in the car a long, flexible lamp cord having on one end a lamp protected by a wire guard and on the other end a suitable plug. Somewhere in the battery circuit there must be connected a suitable socket into which the plug can be readily inserted. If a lamp of 8 to 12 candlepower is used, this arrangement will be found very useful in case of trouble on the road on a dark night.

For automobile use, it is possible to secure tungsten lamps that require 4, 6, or 8 volts and .31 to 3.3 amperes. These lamps give 1, 2, 4, 6, 8, 12, or 16 candlepower, and if properly used, will burn from 200 to 300 hours.

CLEANING THE CAR

60. For cleaning the outside of a car, plenty of clean water and a soft carriage sponge should be used. The sponge should not be rubbed over the car any more than is necessary. After sponging the car, or washing it with a hose, it should be immediately rubbed as nearly dry as possible with a piece of clean chamois. If drops of water are left on the paint, it will become discolored temporarily in spots. While these spots will disappear eventually, it is best not to let them occur at all. A long, narrow brush is useful for cleaning corners and spaces between the spokes of the wheels.

There are always some parts of the painted portion of the car that become oily and greasy. If the car is properly attended to, this oil and grease can be removed by the use of a sponge and soap. The soap should not be strongly alkaline; that is, it should not have much of the property of lye. So-called neutral soaps are found on the market, but it is probable that all of them are slightly alkaline. The grease can be better removed with warm water than with cold water. Hot water can be obtained from the water-cooling system of a water-cooled car after the engine has been run. A separate sponge should be provided for washing the greasy, oily portions of the car. If the grease has become very thick and hard it can be removed more readily by using some gasoline or kerosene. The cleaning should be done as rapidly as possible, in order not to let the gasoline or kerosene remain in contact with the paint any longer than is absolutely necessary.

61. If the car has brass lamps that are bright, it is generally advisable either to remove them or to cover them with oilcloth hoods before washing. Some of the labor of polishing will thus be saved.

For cleaning the glass of a car, the soap known as Bon Ami answers well. This soap is rubbed on moist, allowed to dry, and then rubbed off with a dry cloth. This same soap dissolved in gasoline also makes a good polishing solution

for brightening brass parts. Solarine and other compounds free from acids are also good for polishing brass and copper; and for removing spots from brass, a solution of salt and vinegar is effective.

The external unpainted portions of the machinery, including the engine, always accumulate grease and dust when in service. If these are allowed to collect for some time, it is rather hard to remove them by any mechanical means or by simply rubbing with a piece of waste or cloth. If the car is standing outdoors or in a room that has ample circulation of air, the machinery can be cleaned by applying gasoline with a stiff brush. The gasoline cuts the hardened oil and dust quite rapidly, and the brush aids in its removal. Some operators of automobiles have found it expedient to remove a mixture of grease and dust with a small jet of gasoline, such as is thrown from a plumber's torch when not lighted and when the air pressure in it is high. This method, of course, should not be used except where there is ample ventilation. It would not be allowable in most city garages.

62. Care of Hands in Cleaning a Car.—If it is desired to keep the hands clean while cleaning a car, a pair of gloves should be worn. It is, however, difficult to do this kind of work with gloves on, and the next best thing to do is to give the hands proper care. Care should be taken to avoid scratching, chafing, or chapping them or knocking skin off the knuckles, and in washing the hands, the dirt should be removed with a good quality of toilet soap, warm water, and a brush. Sapolio, sand soap, soft soap, or gasoline should be avoided for this purpose. A preparation called Krystal Soiloff does not seem to harm the hands and is sure to remove dirt and grease. Rubbing the hands with a handful of sawdust saturated with kerosene and then washing them with good soap is also a good way to clean them. It is advisable before beginning to clean a car to fill up all cracks and rough places in the skin and the spaces under the finger nails with good toilet soap, and then avoid contact with the water until the work is finished.

In operations in which acid is to be used, as in soldering with zinc chloride as a flux, it is advisable to wear gloves. Soft cotton gloves or any pair of old gloves will serve the purpose. If gloves are not used, the hands should be protected by rubbing vaseline over them; otherwise, the acid will char the skin.

ROAD RULES AND CUSTOMS

METHODS OF PASSING ON HIGHWAYS, ETC.

63. When driving on the road it should always be borne in mind that each locality has its own laws regulating the movement of vehicles, pedestrians, and other travelers on the highways; also, that in case any of these laws are being violated at the time an accident occurs, the courts will not generally excuse the violator, especially if he is the driver of an automobile that is involved in the accident. This is frequently true, although the violation of the road laws is sometimes for the very purpose of trying to avoid an accident. While the variation of the laws of different localities is exceedingly great, and some depart radically from the general custom, it is well to know what the general custom is. The following statements may therefore be taken to refer to automobiles only, unless other vehicles or travelers are mentioned.

64. Passing of Vehicles.—In the United States, when two vehicles moving in opposite directions approach each other, it is customary for each vehicle to turn to the

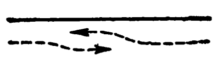


FIG. 6

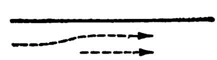


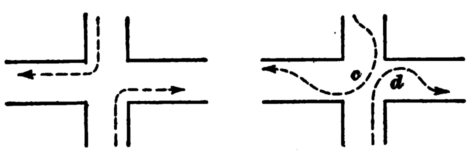
FIG. 7

right in passing, as indicated by the lines with arrowheads in Fig. 6.

If two motor vehicles traveling at different speeds are going in the same direction, and the one going at the higher

speed wishes to pass the other, it should signal with a horn or other signaling device and then pass to the left of the slower vehicle, as indicated in Fig. 7. In this figure the lines with arrowheads indicate the direction of travel, the speed of the vehicle traveling at the faster rate being indicated by the longer line. If the vehicle going at the slower speed is traveling in the middle of the road or near the left-hand side, it must move to the right-hand side of the road in order to permit the more rapidly moving vehicle to pass. The driver of the vehicle moving at the higher speed should not attempt to pass on the right-hand side of the slowly moving vehicle unless the rear driver knows that the driver ahead is aware of his intention and is willing for him to do so. This statement refers to automobiles only in some localities. The slow-moving vehicle always has the right to the right-hand side of the roadway, and if its driver should suddenly turn it to the right-hand side of the road, so as to cut off the passage on that side for the vehicle that wishes to go by, the blame in case of an accident will lie with the vehicle that is attempting to pass the other on the right-hand side.

65. Passing of Cross-Streets.—When passing road crossings, the path that must be followed, according to law, is the same as if there were no crossing; that is, the vehicle must be kept along the right-hand side of the road. In cities where the streets are crowded with traffic, vehicles moving along the main streets running in certain directions, as those extending north and south, are generally given, by law, the right of way over vehicles passing on less important cross-streets. Therefore, when running on a cross-



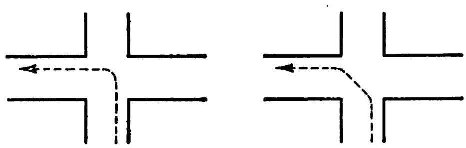
(a) (b)

Fig. 8

street, the driver should observe special care to see that the crossing is clear from vehicles and street cars running along

the main street. No vehicle should be stopped on any street crosswalk or in any street intersection.

66. Turning of Corners.—When turning to the right around a corner, the path to be followed, as prescribed by law, is that shown in Fig. 8 (*a*), and not that shown in (*b*). The requirement is that the vehicle shall remain at its own side of the street, which is the right-hand side. When turning to the left from one cross-street to another, the path to be followed is that shown in Fig. 9 (*a*), and not that shown in (*b*). This path must of necessity be followed if the streets are crowded with other vehicles. The vehicle should be driven out nearly straight in its line of travel to at least the middle of the street; then the turn should be made at a rather short



(*a*) (*b*)

Fig. 9

radius, so as to bring the vehicle along the right-hand side of the other street.

When a street or a roadway is not crowded it is generally more convenient for the driver of an automobile to violate the rules of traffic, especially when turning corners, than it is to follow them. Thus, a corner can be turned at much higher rate of speed, if, instead of following the path indicated in Fig. 8 (*a*), the machine is run to the left-hand side of the street before reaching the cross-street, then swung around rather close to the corner, and then run over near to the left-hand curb, as shown at *c*, Fig. 8 (*b*), thereby following a path of easy curvature. Another easy, but wrong, way is shown at *d* in Fig. 8 (*b*). It should be remembered however, that if an accident is caused by deviating from the path of travel, the courts are not inclined to deal gently with the driver that violates the law.

Accidents of a very unusual nature sometimes occur under such circumstances. Thus, any person may step from the curb into the roadway while watching for a vehicle to come in the prescribed direction, and be entirely unconscious of one approaching the wrong way. It not infrequently happens that children run from a gateway across the sidewalk and jump from the curb into the roadway. While an automobile is passing a standing street car on the wrong side, a passenger may step from in front of the far end of the street car directly in front of an automobile while following the path that is his right of way.

67. Passing of Street Cars.—In passing street cars that are either running slowly or standing to discharge or receive passengers, the general rule is to pass between the

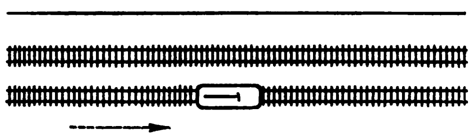


Fig. 10

car and the right-hand curb, as indicated in Fig. 10. If, when there is a double track, an attempt is made to pass on the left-hand side of the street car, careful observation should be made to determine whether the roadway is clear on that side. In some localities, the law forbids a vehicle to pass on the left-hand side of a street car, either when there is a double track or only one track in the street. In others, especially with regard to narrow streets, the law forbids a vehicle to pass between a street car and the right-hand curb when the street car is standing to receive or discharge passengers, but it permits passing on the left-hand side of the street car when there is a double track. In some localities, if there is only a single track, vehicles, such as automobiles, are not allowed to pass by the street car at all when it is standing to receive or discharge passengers.

68. Passing of Animals on Country Roads.—In country districts where the horses or other animals traveling

in the roads are likely to become frightened at automobiles, the laws are generally extremely generous to the driver of an animal-drawn vehicle or to a person riding or leading an animal. In many localities, the driver of an animal-drawn vehicle is free to select his own side of the road, either when the automobile and the other vehicle are approaching each other or when the automobile wishes to pass the slower-moving animal-drawn vehicle from the rear. Automobile drivers should take care to observe which side of the road the driver of the wagon or the person riding an animal indicates as the one he selects for passing. While at first such a law might seem without basis, there are really very excellent reasons for it. It frequently happens that a team of horses or other animals will pass an automobile when one of the animals is on the side next to the automobile, while the other animal of the team would cause trouble if brought next to the car while passing it. There is also very frequently the condition of the roads to be considered with regard to safety in case of fright of the animals while passing a car, as when one side of the road is precipitous and dangerous, while the other is a wall, bank or level that is not dangerous.

The law in many rural localities, and also in some cities, requires that the driver of an automobile shall stop if the driver of an animal-drawn vehicle signals him to do so, as by holding up one hand. In some cases, this law requires that not only shall the travel of the automobile be stopped, but also its engine, so that there will be an entire absence of noise, motion, and smoke about the car.

While the following is not known to be a written law in any locality, it is certainly expected, as indicated by some courts, that the driver of an automobile shall get out and lead the frightened horse, mule, or other animal past his automobile if so requested by the driver of the animal. It is probably not often that such a courtesy would be refused in the case of women and children. The person leading a frightened horse should take a firm hold of both reins, about 6 inches below the mouth, and walk forwards as much to one side as practicable.

69. The driver of an automobile should give some thought to the possible behavior of animals on the roadway. A horse that becomes frightened generally shows indication of fright while far enough away for an automobile to stop and give the driver of the horse an opportunity to get out to hold it. A mule, however, generally does not notice the approach of an automobile until it is within a few feet of him, and then, if much frightened, lunges in a violent manner and is apt to wheel directly across the road in front of the automobile. When a pair of mules is hitched to a wagon having a tongue, the one nearest the automobile not infrequently swings around so as to stand nearly at right angles to the wagon tongue, with his head projecting out into the portion of the roadway that belongs to the automobile. An ox, a cow, a pig or a chicken has the characteristic behavior of running along the side of the roadway, trying to keep ahead of the car when the car is approaching at a moderate speed, and then darting, or attempting to dart, across the road in front of the car.

ORDINARY PRECAUTIONS

70. It is not advisable to run alongside a moving street car slightly back of the front end of the car. A pedestrian frequently runs across in front of a moving street car, and if the automobile is running slightly back of the front of the street car and close to it, he is liable to jump directly in front of the automobile.

Running behind a street car at a less distance than that in which the automobile can be stopped at the rate of speed it is traveling is dangerous on account of the possibility of running into an excavation in the track. A street car can, of course, run safely over the excavation, but an automobile cannot unless it happens to be traveling on the rails. An automobile should not be run too close to the rear of a street car, even if the driver can stop the automobile as quickly as the street car can be stopped, because there is the danger, when turning from immediately behind

the street car, of running into a street car or a vehicle coming in the opposite direction but, at the moment of turning, hid from view by the car ahead. It is also dangerous to attempt to cross two street-car tracks ahead of two street cars coming in opposite directions if there is the least doubt about there being plenty of room. In such a case, if the automobile is caught between the two cars or hit by either one of them, considerable damage to the automobile and occupants may result.

71. An automobile should never be run too close behind another automobile. This is an extremely dangerous practice when running at high speed, for if the forward car for any reason whatever suddenly slackens its speed, the rear car may run into the car ahead and thus cause considerable damage to one or both cars.

A not infrequent kind of accident on a dark roadway is the running into the rear of a wagon without lights by an automobile that carries only kerosene lamps and is not provided with headlights by means of which objects some distance ahead can be seen.

Some city laws require the driver of any vehicle when desiring to stop on the left side of the street to make a complete turn, so as to bring the right side of the vehicle next

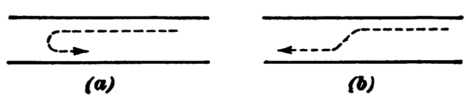


Fig. 11

to the curb, as shown in Fig. 11 (*a*), and not as shown in (*b*), which is the more usual method. Slowly moving vehicles are also required to keep near the right curb, allowing more rapidly moving vehicles to keep nearer the center of the street.

72. In general, it should be remembered in driving a car that sufficient caution should be observed to avoid accident, even though the drivers of other cars are not obeying the law or are absent-minded and heedless. It is not an unusual

thing in cities for a pedestrian to step from the curb into the path of an approaching car while looking directly at it. This, of course, is done on account of absent-mindedness or absorption in other matters. Aside from the action of the law in such a case, few drivers would care to injure any one under such conditions.

73. Effect of Rails on Tires.—Rubber tires are easily cut and injured when an automobile is run along a street-car track of the type that has a groove for the flange of the street-car wheel and sharp edges on the flange of the groove. The edges of the flange are apt to be especially sharp on grooved rails at street corners and at switches and turnouts. The sharp edge of a rail cuts through the rubber and soon cuts the fabric of the tire, so as to weaken and injure it beyond repair except in a manner that is so costly as to be practically prohibitive. The tongues, or points, of rail switches are sometimes sharp enough to cut the tire. Generally, car rails without flanges do not have any parts sharp enough to injure the tire by cutting it.

While riding on the street-car track is generally very comfortable, there are certain accompanying risks when the track and street are wet and slippery or greasy. When turning out of the track under such conditions, it is generally necessary to swing the steering road wheels to a considerable angle with the track, in order to cause them to leave the track, but even if this is not necessary, the rear wheels will not generally leave the track until the body of the car has made a considerable angle with it. Then, when the rear wheels leave the track, the rear of the car swings over suddenly, and, if the roadway is slippery, the car may turn completely across the road, provided the rear wheels do not strike the curbing before this occurs, or even turn completely around so as to head in the opposite direction. This is most likely to occur when either the engine is delivering power to the driving wheels or when the brakes are strongly applied. In either case, the behavior of the car is dangerous. When crossing the rails of a track in wet weather, or when the street

and track are slippery, the crossing should be made at a considerable angle with the track and not with the car running nearly parallel to it, for the same reasons as those just described.

74. Skidding. — An automobile will skid and slide more easily on paved streets that are only slightly wet, as after a light rain, or sprinkling, than it will on pavement that is throughly wet, as by a heavy rain. This is due to the fact that a dirty, wet pave is much more slippery than a pave that has been washed clean, however wet it may be.

When driving along the sides of an inclined roadway, especially one that is clayey and wet, the speed should be kept very low, for there is danger that the car may slide at any moment to the low side of the roadway. The mud at the side of the roadway is generally softer than at the higher central part, and this has a tendency to throw the car to the side of the road, which will generally result in a serious accident unless the speed of travel is slow or the side of the road is unusually flat and in good condition.

Either a spinning wheel or a locked wheel will slide more readily than one revolving at a slow speed; hence, if the wheels start to skid or slide sidewise, do not put on the brakes so hard as to lock them, nor put on enough power to spin them around, but lower the speed as much as practicable and put on the brakes gradually or intermittently. Imperfectly balanced hub brakes, one gripping quicker or more tightly than the other, are a frequent source of side-slipping, as only one locked wheel will nearly always throw the rear end of the car around sidewise. When a car starts to skid, try to steer so as to keep the car parallel with the road.

75. Narrow, deep ruts in either macadamized or earth roads are injurious to the sides of a tire when the wheel is traveling in such a rut. The rut may be of such a width in places that the wheel will drop down into it and bind the tire. The steering gear might also be broken or the car be thrown from its path of travel in case the rut is very deep. Such ruts should be carefully avoided.

When running over newly broken stone on a roadway, the speed should be kept down, both because the car is not easily steered when the stone is loose and because there is greater danger of a tire becoming pierced by the sharp point of a stone when the speed is high than when it is low. Some of the stones used on roadways have in them small particles of flint or other hard stone that sometimes break to a very sharp, triangular point. If one of these points strikes endwise against the tire, it is liable to cause a puncture.

TROUBLES AND REMEDIES

(PART 1)

AUTOMOBILE-ENGINE TROUBLES

STARTING AND RUNNING DIFFICULTIES

SYMPTOMS, CAUSES, AND REMEDIES

1. Diagnosing Troubles of Automobile Engines. To manage successfully an internal-combustion engine—especially one that works under such a variety of conditions, often very severe, as the automobile engine—it is first of all necessary for the operator to make good use of his reasoning faculties.

The symptoms of derangement, when taken singly, are often such as may be caused by any one of several possible defects. In nearly every case the defect, whatever it may be, will produce several symptoms, a careful study of which will lead to the elimination of causes that do not tally with all the symptoms; as, for instance, causes affecting all cylinders when only one or two are misbehaving, or vice versa. When the user has reached this point, generally a short further investigation of the points at which trouble of that particular sort is most likely to occur will lead him to the discovery of the true cause. The cause of loss of power, due to such faults as a loose battery connection, a sticking inlet valve, or a bit of dirt in the carbureter, will at once be recognized in its true character by the experienced operator. The only way to

attain final proficiency in these things is by extended experience with the particular engine in hand; but, on the other hand, there is no excuse for the aimless groping of many inexperienced users, who will often send needlessly for a tow, or will pull an engine to pieces in their search for some simple fault that might be located by intelligent diagnosis.

2. Causes of Refusal to Start or of Sudden Stoppage.—The fundamental reasons for an engine refusing to run or of a particular cylinder refusing to work may be summed up as due to (1) no spark, (2) no mixture, or (3) wholly wrong mixture. These cover all the possible causes, which may be enumerated as follows:

1. Switch not closed.
2. Gasoline not turned on.
3. Carbureter not primed, or (rarely) primed too much, or flooded.
4. Weak battery.
5. Gasoline stale or mixed with kerosene.
6. Gasoline too cold to vaporize.
7. Dirt or waste in carbureter or gasoline pipe.
8. Mud splashed into air intake.
9. Water in carbureter.
10. Soot on the spark plug or contact igniter.
11. Water on spark plugs.
12. Broken spark-plug porcelain.
13. Grounded wire (generally secondary).
14. Broken wire (generally primary) or loose connection.
15. Very bad adjustment of the coil tremblers.
16. Defective spark coil or condenser (rare).
17. Broken igniter spring.
18. Defective high-tension circuit.
19. Broken valve stem, spring, or key.
20. Valve cams slipped (rare).

3. Causes of Irregular Firing or Misfiring.—The principal cause of misfiring is irregular sparking, which may be due to a variety of causes. Irregular sparking may be caused by the following:

1. Spark plugs or contact igniters defective or covered with soot.

2. Weak battery.

3. Broken wire, making intermittent contact through the vibration of the car (generally found in the primary circuit).

4. Loose connection at a binding post or anywhere in the primary or low-tension circuit.

5. Wire occasionally grounded through vibration of car. This is generally found in the secondary circuit, and it is not necessary for the bare wire to make contact with the metal into which this secondary current is escaping. If the insulation of the secondary cable is weakened and the cable is lying loosely on a metal part, the spark will often jump through the insulation.

6. Timer contact surfaces roughened by sparking.

7. Wabbling or defective timer.

8. Poor trembler adjustment.

9. Trembler sticking at high speeds, due to inertia of heavy armature.

10. Insufficient pressure on timer contacts.

Some other causes of irregular firing are as follows:

1. Valve spring weak or broken.

2. Sticking, binding, or broken valve, or one badly in need of grinding.

3. Particle of carbon under valve.

4. Spray nozzle closed intermittently by loose particles of dirt, etc.

5. Air valve of carbureter sticking or binding.

6. Mixture too rich or too lean.

7. Lubrication excessive or oil not suitable.

8. Water in cylinder on account of cracked or porous cylinder, or loose plug in cylinder wall.

A sticking inlet valve, which stays open when it ought to close, will cause irregular firing and occasionally back firing.

A very lean or a very rich mixture may be ignitible only by a strong spark. It can always be distinguished from ignition troubles by the fact that the explosion impulses,

when they occur, are of much less than normal strength. If the mixture is too weak, the explosions are likely to occur every other cycle. If the mixture is too rich, there will sometimes be explosions in the exhaust pipe and muffler; if it is too lean, there will ordinarily be back firing into the carbureter.

4. **Causes of Weak Explosions.**—The causes of the explosions being weak are briefly as follows:

1. Mixture too lean or too rich.
2. Leakage of compression.
3. Mixture diluted with exhaust gases.
4. Spark timing later than it should be, in one or all cylinders.

If the trouble is in the mixture, the explosions are regular, unless the mixture is so defective that it sometimes fails to ignite in spite of the spark occurring regularly. The same will be true in any case where, as is usual, the cause of the weakness is unconnected with any irregularity in sparking.

The causes of weak explosions may be enumerated more fully as follows:

1. Dirt or waste in carbureter or gasoline pipe, causing weak mixtures.
2. Stale gasoline.
3. Air intake partly obstructed, causing rich mixture.
4. Bad carbureter adjustment.
5. Trouble with float.
6. Choked muffler.
7. Lack of oil on piston, or oil that is too thin.
8. Leak through valve (generally the exhaust valve).
9. Leaky spark plug.
10. Valve timing wrong. This is most likely due to the fact that the cam-shaft, etc. have been taken out and replaced with the gears in incorrect angular relation. It may, however, be caused also by wear of the cams, push rods, or valve stems, by spring in the cam-shaft or valve lifters, or by the slipping of cams.
11. Broken or worn piston rings.

5. Causes of Failure to Keep Engine Going.—If the engine starts, but soon slows down and finally stops, the trouble may be due to any one or a combination of the following causes:

1. No fuel in tank.
2. Fuel does not flow freely to carbureter, the piping being clogged or the vent hole in gasoline tank being closed.
3. Broken connection in fuel supply pipe.
4. Valve closes suddenly in gasoline supply pipe.
5. Water in carbureter.
6. Weak battery.

6. Causes of Sudden Stoppage of Engine.—If an engine has been running well and stops suddenly, and the cause of the trouble is known not to be due to breakage of an important part, the following causes may be looked for:

1. Fuel tank empty.
2. Dirt in carbureter.
3. Primary wire broken or short-circuited.
4. Vibrator stuck in a single-cylinder or master-vibrator ignition system.

7. Causes of Back Firing Into Carbureter.—If explosions occur in the carbureter, the probable causes are:

1. Mixture too lean.
2. Inlet valve binds or valve spring is weak.
3. In a two-cylinder engine with the spark plugs in series, back firing may be due to retarding the spark excessively when starting the engine.

8. Causes of Slow But Constant Decrease of Power. The most probable causes of the power of an engine decreasing slowly and constantly are the following:

1. Vent closed in fuel-supply tank, provided it is of the gravity type.
2. Insufficient pressure in compression fuel tank. This may be due to a leaky or binding check-valve in the compression pipe, or to the tank not being tightly closed.
3. Valve gradually jarred shut in the fuel pipe.

4. Poor compression on account of a valve becoming leaky in a single-cylinder engine.

9. Reasons for Failure of Engine to Develop Full Power.—A failure of the engine to develop its full power should not be confused with frictional resistance in the transmission system, or dragging brakes. The chief reasons for this trouble in the engine itself are:

1. Back pressure on account of a choked muffler. Opening the muffler cut-out or relief valve will at once indicate whether or not this is the cause of the trouble.
2. Lubrication insufficient, especially in the cylinder.
3. Overheating.
4. Compression leaks at the valves, around the piston, or through a porous cylinder wall or a loose cylinder plug.
5. Particle of carbon or other dirt under a valve.
6. Valves not properly timed.
7. Mixture too rich or too lean.
8. Ignition spark weak on account of weak battery. The spark does not always occur early under this condition.
9. Water entering cylinder from water-jacket.
10. Timer slipped on shaft, causing late spark.

10. Reasons for Engine Not Running Slowly and Pulling the Car.—It sometimes happens that an engine will run at high speed and pull the car, but will fail to pull the car when slowed down. The probable reasons for such behavior are as follows:

1. Carbureter not adjusted properly.
2. Magneto magnets weak, or magneto not speeded to suit the engine.
3. Compression in the cylinders poor.

11. Causes of Engine Not Running at High Speed. If it should be found that an engine will run well at low speeds, but cannot be speeded up to high speed, the probable causes are the following:

1. Carbureter not adjusted properly, or not receiving fuel fast enough.

2. Weak battery.

3. Vibrator of igniter too heavy or set too tight to respond quickly to the action of the primary current.

4. Timer defective.

KNOCKING OR POUNDING

12. Mechanical Causes of Knocking.—Undoubtedly the sense of hearing is more useful in detecting irregularities in the running of an engine than any other sense. By means of the sounds produced, the engine talks to the operator, and with a little intelligent study he will soon understand the language. Even at a distance it is often possible to tell whether an engine is running regularly or whether, as indicated by the sound of the exhaust, some of the charges admitted to the cylinder are expelled without being exploded. Standing in close proximity to the engine, the operator may distinguish a variety of sounds indicating defects about the engine and calling attention to the necessity of applying proper remedies at the first opportunity. By opening the muffler cut-out, provided the engine is fitted with one, any irregularity in the running can be more readily detected.

13. Knocking in automobile engines may be due to looseness or rattle in some external part, owing to nuts having worked loose or to bolts being sheared off or being too small for their holes. Knocking due to such causes is readily detected by a careful inspection while the engine is running. This inspection may be aided by laying the hands on parts suspected of being loose, when vibration will easily be felt; also by careful scrutiny with an electric flashlight for evidences of movement where two parts are bolted together.

About the most likely place to find looseness of this description is in the holding-down bolts that secure the engine to the frame on which it is mounted; but in certain horizontal engines it may also be found that the caps over the main bearings are loose, owing to the fact that they have not been properly tongued into the bottom halves or pillow-blocks of the bearings. Looseness at either of these two

points should be remedied in the repair shop, as it always necessitates the substitution of larger bolts, aided perhaps by dowel-pins; and in the case of the bearing cap it may be necessary to make an entirely new cap, with proper tongues fitting into grooves that must be machined or chiseled in the pillow-block.

14. A prolific cause of knocking is looseness due to wear in the bearings of the main shaft, the crankpin, or the wrist-pin. In a four-cylinder vertical engine, the main-shaft bearings may be quite loose without causing a knock, because the weight of the shaft and flywheel holds the shaft down; but a horizontal engine will, under certain conditions of speed and load, pound with a small amount of looseness. Only a very limited amount of looseness should be permitted in the main-shaft bearings of any engine, both on account of the danger of springing the shaft and because a bearing worn beyond this extent is liable to begin cutting, as it is difficult to keep sufficient oil in such a bearing.

15. Looseness in the flywheel bearing of a vertical engine is disclosed by putting a jack or a lever under the flywheel and working it gently up and down. In the case of a horizontal engine it is necessary to move the shaft approximately in line with the pressure of the explosions, and a lever will have to be applied to the flywheel or shaft in whatever manner seems most practicable. Occasionally, looseness of the shaft can be detected by rocking the flywheel back and forth against the compression in the cylinder. If the pull of the sprocket chain comes on the engine shaft, looseness in the adjacent bearing may possibly be detected by alternately stretching and relaxing the chain, which can be done by grasping it midway between the sprockets and pulling it up and down as far as it will go.

Another very good way to disclose looseness in the main bearings of any car having a planetary transmission gear on an extension of the engine shaft is to tighten one of the friction bands of this gear by the appropriate lever, usually the low-speed or the reverse lever. It very rarely happens

that the tension of these bands is exactly balanced, so as to impose no radial pull on the shaft. Tightening the band will move the shaft to whatever extent the adjacent bearing has worn.

A novice should not attempt to refit the main-shaft bearings, as this operation requires a great deal of skill and experience for its correct execution.

Wear in the crankpin bearings is disclosed by setting the cranks at about half stroke and then rocking the shaft back and forth.

16. Knocking in the wristpin, due to wear of the pin and its bushing, is not among the more common troubles and does not need to be taken care of at once unless aggravated. It is well, however, not to neglect this trouble too long, as the bushings and the pin will be worn out of round so badly that they cannot be used. A good engine will run a car many thousand miles before any replacement is demanded at this point. When it is taken out, the wristpin should be calipered all around. If it is out of round, it should be ground true; or, if this is impracticable, a new pin will have to be supplied and the bushing reamed or scraped to fit. This, of course, should be done in a repair shop.

17. Knocking is occasionally due to the wristpin and the crankpin not being exactly parallel. This causes the connecting-rod to oscillate from end to end of the wristpin and crankpin bearings; and if, as is customary, there is one-sixteenth or more of end movement in these bearings, the knocking may be very noticeable. If, as is likely to be the case, it is impossible to make the pins parallel, the only recourse is to take up the lost motion at the end of one or the other bearing, and possibly both bearings, by the use of washers or cheeks soldered to one end of the bushing and brasses. This cause of knocking is not common, particularly in the better class of engines.

18. The best construction is to secure flywheels to short shafts by bolting them to flanges instead of keying them.

Sometimes, however, a flywheel is held on by a common key or by two keys 90° apart, and frequently it will work loose on its keys. This will inevitably result in a knock, which will be very loud if the engine has fewer than four cylinders. The crank-case should be opened and the cranks blocked so that the shaft cannot turn; then force should be applied to the flywheel to disclose the looseness, if any. Sometimes the flywheel will be so tight on its shaft as to resist turning in this manner by using any ordinary force. In this case, it is best to take the car to a repair shop if a thorough search has failed to disclose any other cause of the noise.

A sprung shaft will always cause knocking, and also rapid wear and cutting of the bearings.

19. Combustion Knocks.—Besides the mechanical causes of knocking, there is a class of knocks that may be called **combustion knocks.** Such knocks are altogether distinct from the preceding, in that they may occur without appreciable looseness in the bearings. They are due to excessive rapidity of combustion, coupled generally with too early ignition, the charge being completely burned before the piston has reached the end of the compression stroke. The most obvious cause of combustion knocks is too early ignition, as when running up a hill without suitably retarding the spark. A contributing cause is a slightly weak mixture, because a mixture of this kind burns faster than a normal or overrich mixture. Pounding in particular cylinders of a multicylinder engine may be due to unequal rapidity of combustion, which itself may be due to unequal charges, as when the valves are unequally timed, or to irregular spark timing, such as may result from a wabbling timer or badly adjusted vibrators. If the timer contact surfaces have been roughened by sparking or by wear, they will cause the contact maker of the timer to jump when running fast, and therefore to make erratic contact, resulting in irregular firing. The knocks are not necessarily violent, and they may sound a good deal like the knocks due to loose bearings, except that, if caused by faulty action of timer or vibrators, they will occur irregularly.

20. Pounding due to too early ignition is not always due to failure to retard the spark; in fact, a partly compressed charge may often be ignited before the spark occurs by coming into contact with incandescent particles of carbon that adhere to the combustion chamber or piston head. This defective action is called **preignition.** Preignition may also be caused by insufficient cooling of the cylinder, due to a shortage of cooling water, to portions of the water-jacket becoming filled with deposits of any kind, or to improper circulation of the water, any one of which will be indicated by the boiling of the water or by the smoking of the exterior of the engine.

Imperfections in the surfaces of the combustion chamber—such as sand holes or similar cavities, and small projections on any surface exposed to the heat of combustion—or parts that are not sufficiently cooled while the engine is running under a fairly heavy load, may also cause preignition.

21. Premature ignition manifests itself by a pounding in the cylinder, and if permitted to continue, it will cause a drop in speed, finally resulting in the stopping of the engine. It will also put an excessive amount of pressure on the bearings, especially the connecting-rod brasses, and cause them to run hot even when properly lubricated. After a shut-down due to premature ignition and a short period during which the engine is idle, allowing the overheated parts to cool off, it is possible to start again without difficulty and run smoothly until the conditions of load will cause a repetition of the trouble.

If the engine has two or more cylinders, and only some of them inclined to preignition, the result is that it is impossible to time the ignition correctly for all cylinders. The cylinders having a tendency to preignition must receive a late spark to prevent combustion from being completed too early, while the other cylinders will require an early spark. Thus, the engine cannot possibly be made to develop its full *torque*, or turning moment, unless it is running so fast that the tendency to preignition may be neglected.

True preignition results almost always, except at the highest engine speeds, in the charge being completely burned before expansion begins, and it is easily distinguished, especially if the engine is taking full charges, by the resulting sound, which is a sharp, metallic *bing! bing! bing!* closely resembling that produced by a hammer striking a block of cast iron. It is dangerous to run the engine slowly, and this is true even if only one cylinder is preigniting. If the engine is running at good speed, with an early spark, the symptoms will be those of rapid combustion in the cylinders affected, namely, a hardness in the sound of the explosion, without actual knocking, while in the other cylinders, if any, the explosion will be soft. As the speed of the engine is reduced and the spark is retarded to suit, the hard sound of the explosions gives place to unmistakable knocking. A good test for preignition due to carbon is to start the engine with everything cold, and run the car at high speed up the nearest hill before the water in the radiator has had time to get hot. The *bing! bing! bing!* then is a sure sign. If the carbon deposit is very great, the engine may knock when gearing up, provided this is done quickly with the engine running rather slowly.

22. The remedies to be applied to overcome preignition, according to the source of the difficulty, are as follows: Remove the carbon deposit, plug the sand holes, or blowholes, and remove the sharp projections not intentionally made on any surface subjected to the heat of combustion; also, keep the water system full of water, clean it out if stopped up or dirty, and make sure that the water circulates properly.

A small quantity of carbon will give no trouble, but as the deposit thickens, some portions of it will remain incandescent from one explosion to the next and will ignite the fresh charge at some point in the compression stroke, depending on conditions. The fact that the charge is not ignited until some time during compression is due to the fact that the more highly it is compressed, the more easily it will ignite. Usually, though not always, an engine that prematurely ignites the charge on account of an excessive deposit of carbon will

continue to run by spontaneous ignition for several seconds after the igniter switch has been opened. If the throttle cannot be closed tight enough to stop the engine when it is running idle, it can be stopped by throwing in the clutch or otherwise engaging the transmission mechanism. The hammering due to preignition, as would be expected, is most marked when the engine is running slowly with the spark suitably retarded, and it will generally manifest itself when hill climbing, owing to the fact that the throttle is then wide open and the spark necessarily retarded to suit the slow speed of the engine.

23. Causes of Carbon Deposit in Cylinders.—The deposition of carbon in the cylinder is generally due to an overrich combustible mixture, an excessive amount of lubricating oil, or an unsuitable quality of lubricating oil. A deposit of carbon will sometimes accumulate gradually even when the lubricating oil is of the right quality and used in proper amount and when the combustible mixture is apparently of the correct proportions. Carbon is probably deposited on the piston head only when it becomes very hot. In such cases, the incoming mixture strikes the piston head and a portion of it is dissociated, or split up, by the high temperature of the piston, so that part of the carbon is liberated and deposited on the piston head. The carbon is deposited in two forms. One form is similar to that of ordinary soot; the other is more like coke.

24. Carbon in the form of coke is not generally found anywhere except on the piston head, where it collects so as to form a rough surface with small projections. This carbon is liable to become very hot and cause preignition. If a flake of the carbon breaks loose, it may lodge under the exhaust valve and thus cause a temporary loss of compression and power; or, it may work down between the piston and cylinder wall and produce a scratch, or score, on one or both.

Soft soot-like carbon is generally deposited over the entire surface of the cylinder space, except possibly the piston head. The portion that settles on the bore of the cylinder is gener-

ally scraped off as rapidly as it is deposited, either by the piston or the piston rings. The carbon that is scraped off by the piston rings mixes with the lubricating oil and sometimes collects around and under them, thus preventing their elastic action. This is especially apt to occur if the lubricating oil has a tendency to leave a gummy deposit as it is evaporated or burned in the cylinder.

Soft carbon also deposits on the spark plug to an extent that depends at least somewhat on the form and material of the insulation in the plug. If the carbon settles to any great extent on the insulation, the plug becomes short-circuited and misfiring results. A portion of the carbon that deposits on the other parts of the wall of the combustion chamber generally does not produce any serious results until the deposit becomes thick enough to flake loose or form projections that become heated so as to cause preignition of the charge. The portion that flakes off may lodge temporarily under the exhaust valve.

In two-cycle engines, carbon sometimes collects in the exhaust ports so as to choke them. This, however, is not so likely to occur in the more modern engines with large ports as in engines with small ports and small exhaust passages. Practice has shown that many of the earlier two-cycle engines had ports and passages entirely too small for high speed.

25. Removal of Carbon From Engine Cylinders. The soft carbon can be removed more or less effectively from the cylinder by means of a liberal supply of kerosene. The kerosene should preferably be put in the cylinder when the engine is hot, cranking the engine as many times as it has cylinders and permitting it to stand for some time, as overnight. If the piston is then worked back and forth or the engine rotated by hand, the soft-carbon deposit can generally be washed off completely from the cylinder walls, or it may be blown out through the exhaust if the engine is run a few minutes. It is also sometimes advisable to draw off the lubricating oil from the crank-case and put in a liberal supply

of kerosene. Then, after the kerosene has been allowed to stand in the cylinders overnight, the engine should be run for a few minutes under its own power, the splashing of the kerosene serving to wash away any carbon particles that would otherwise adhere to the lower ends of pistons and cylinders. The soft carbon will also be at least partly removed in this manner from around and under the piston rings.

There are various compounds on the market that, according to claims made for them, will cut the carbon loose rapidly and effectively without injuring the parts of the engine. Some of them remove both hard and soft carbon without apparent injury to the engine.

The hard-carbon deposit on the piston head can be removed by scraping. The method of scraping depends, of course, on the construction of the engine. In some forms, a scraper can be inserted through the opening that remains after removing one of the valves. Some automobile engines are so constructed that the cylinder head may be removed without disturbing the piston and valves; in such cases, the part of the cylinder in which carbon deposits occur is readily accessible.

COOLING AND LUBRICATION TROUBLES

COOLING-SYSTEM DIFFICULTIES

26. Lack of Water in Radiator.—Lack of water in the radiator of the cooling system for an automobile engine is indicated by the rapid emission of steam, provided there is sufficient water to enter the engine jacket; by overheating and smoking of the engine, followed by laboring, groaning sounds, owing to the oil being burned away as fast as it is supplied to the pistons; and, if the engine still continues to run, by expansion and seizure of the pistons in the cylinders.

Trouble from lack of water is due to carelessness in not filling the tank before starting; leakage in the radiator, pump, or piping; accidental opening or breakage of the drain cock at the lowest point of the circulation system.

The remedies for trouble of this kind are apparent on inspection. If the engine becomes overheated so that the water boils rapidly away, and there is reason to think that the upper portion of the water-jacket is dry, the engine should be allowed to cool before water is added; otherwise, the sudden contraction may warp or even crack the cylinders or it may cause the cylinders to contract and seize the pistons. If the water gives out when at some distance from the nearest source of supply, the engine may be allowed to cool off and the car may then be run with the throttle nearly closed and the spark advanced as much as it will bear without knocking. This may be kept up sometimes for ½ mile before it is necessary to stop to cool the engine. The crank-case should be liberally supplied with oil to prevent the pistons from becoming dry, or, if a sight-feed oil cup is used on the cylinder, it should be set to feed quite rapidly. The engine should be stopped at the first sign of distress, as indicated by a groaning sound, turning with difficulty, or knocking caused by preignition due to hot cylinders.

27. Obstructed Circulation.—An obstruction to the circulation of the cooling water elsewhere than in the radiator will cause the bottom of the radiator to remain cool while the top is probably boiling hot.

Obstructed circulation may be caused by a broken pump, a broken driving connection to the pump, or a slipping belt or friction pulley, provided the pump is driven in this manner; by waste or some similar material that has lodged in the pump or piping; or by a piece of hose lining that has become loose and acts as a flap valve or check-valve to close the pipe partly or completely.

Air or steam in the water system sometimes prevents circulation when all, or rather nearly all, the water has been drawn off and the system has just been refilled. If there is an air valve at the pump or in the higher portion of the water system, it should be opened to allow the air or steam to escape. Sometimes when the water has become very hot, steam collects in the pump and temporarily prevents circulation

of the water. A check-valve placed near the outlet of the pump will generally prevent this occurrence, however.

When the water stops circulating, the engine naturally heats rapidly and there is a consequent decrease of power. If the engine is kept running long under this condition, some injury may be done to the cylinder and piston. In many cases, the frictional resistance to the motion of the piston may become so great that the engine will stop of its own accord.

The remedies for defective circulation of the cooling water will usually become apparent on inspection.

28. **Fan Troubles.**—A simple trouble, but one likely to be mistaken by the novice for radiator or circulation trouble, is the slipping of the fan belt. The belt should be tested occasionally, and not allowed to get so loose that the fan pulley can spin inside it. It does not have to be tight. If the fan does not run at full speed so as to draw air through the radiator and force it against the engine with sufficient rapidity, the cooling water may become so hot as to allow the cylinders to overheat.

Some types of gear-driven fans are provided with a spring-closed friction clutch, so that they will not be suddenly jerked when the engine starts. A fan thus driven may fail to run at full speed because the spring of the friction clutch either is too weak or is broken. A fan may of course stop entirely on account of a broken belt or gear.

In an emergency, as when the fan belt is lost, the fan may be driven temporarily by means of either a strong piece of cord or a piece of belt lacing. The latter, cut into strips, can be purchased from dealers in belting and mill supplies. Cord such as is used for chalk lines in carpentry or for deep-sea fishing can generally be purchased of any hardware dealer. It may be necessary to put on several separate bands of the cord or belt lacing in order to drive the fan at full speed.

If a belt slips on account of too much oil, the pulley and belt should be cleaned with gasoline.

29. Frequently, a belt will break at the connection between its ends. A very simple, inexpensive form of con-

nection that can be readily carried for making repairs in such a case, or made as required, is a wire bent into a double-hook form. Three styles of such belt hooks, or fasteners, are illustrated in Fig. 1. Each form is made in four sizes. To insert a fastener, each end of the belt is pierced so as to form a hole to receive one end of the hook. This hole can be made with a small knife blade, keeping the back of the blade next to the end of the belt, or, better, with a brad awl, or a punch. In the absence of such tools, the handle end of a file may be used. The point of the file must of course be sharp, and a wedge-shaped point will be found more suitable than a round one. After a fastener is inserted, its ends should be bent down with a pair of pliers or in any way that is convenient.

In the absence of belt hooks or suitable wire for making them, a piece of fence wire, telephone wire, or wire such as is used for baling hay and straw may prove suitable. Small

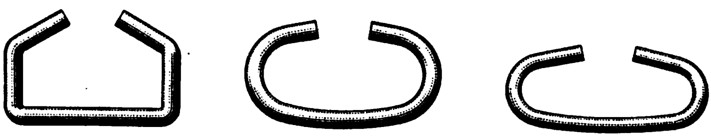


FIG. 1

soft-iron wire can also be used to fasten the ends of a belt together. In using this kind of wire, it should be run through the holes several times, in the manner of a lacing. A long, slender wire nail with the head cut off also makes a very suitable belt fastener.

30. Scale or Sediment in Radiator.—The presence of scale, sediment, or oil in a radiator is indicated when the whole radiator becomes unusually hot or when steam formed in the jacket forces water out of the overflow pipe of the radiator. Overheating of the radiator because of scale should not be confused with that due to a large decrease in the radiation of heat because the outside of the radiator is covered with an excessive amount of dirt or mud, nor with that due to the production of an unusual amount of heat in the engine.

Scale will deposit from hard water if the temperature of the water is allowed to approach the boiling point. A simi-

lar scale, almost impossible to eliminate, will crystallize from calcium-chloride non-freezing mixtures if these are allowed to become supersaturated.

31. Impure water used in the cooling system may leave either a coating over the surfaces with which it comes in contact or sediment where it has an opportunity to settle. If oil or grease becomes mixed with the water, an oily deposit will be left on the walls of the enclosing space. All these deposits reduce the cooling efficiency of the radiator.

Soft mud can be more or less completely washed out by attaching a hose to the cooling system and forcing water through it as rapidly as possible. The water should be sent through first in one direction and then in the other. There should be a free outlet from the system, so that the pressure in it will not become high enough to bulge or burst the tubes of the radiator. Ordinary dirt can also be cleaned out by a strong, hot solution of lye, which should be used with care, as it burns the skin badly.

Oil and grease can be removed from the inside of the radiator and other parts of the cooling system by putting in a liberal supply of either kerosene or kerosene and soap and then running the engine until this cleaning compound becomes hot and has time to act on the oily deposit. The cooling system should be drained and washed before filling again with clean water. Mud on the outside of a radiator can be removed by means of water or water and soap, and for the removal of external oil and dirt, gasoline applied with a brush or a swab will be found effective.

32. The removal of scale deposited by hard water may prove to be a difficult operation. If the chemical nature of the scale is known, a chemist can generally advise what substance will dissolve or loosen it. In many cases, however, the substance that will act on the scale will be injurious to the metal of the radiator or other parts of the cooling system. For this reason, it cannot be used, except in some cases where the action on the scale is so much more rapid than on the

metal that the scale can be dissolved, or at least loosened, before appreciable injury is done to the metal.

The scale deposited by the hard water that is found throughout a considerable portion of the United States can be softened and removed with a solution of carbonate of soda, which is simply common washing soda. The proportions of the solution are about 2 pounds of soda crystals to 1 gallon of water. Before putting in the solution, the system should be thoroughly drained. The water drained out should be measured, and then an equal quantity of the solution made up and put into the cooling system so as to fill it. The solution can be left in for 8 or 10 hours and then drawn off, after which the system should be washed until the water that flows from it is clear. The scale is loosened by the carbonate of soda and washes out in the form of sludge, which looks like mud.

33. A radiator badly choked with lime scale is practically useless, although, if it is made entirely of brass and copper, the scale may sometimes be removed by the use of a dilute solution of hydrochloric acid in the proportion of about 1 part of acid to 10 parts of water. This solution should be left in the radiator long enough only to loosen the scale, after which it should be drawn off and the radiator washed out. In doing this, a good plan is to disconnect the radiator from the engine so as to confine the effects of the acid. The scale in the water-jacket space of the engine can be scraped off from the accessible portions. Scale is not likely to deposit to any great extent in radiators that have thin, flat vertical tubes, especially if there is rapid forced circulation of the cooling water by a powerful circulating pump.

There is seldom enough oil in the cooling water to cause much coating of the cooling surfaces. About the only place that oil can get in is at the circulating pump when it is excessively lubricated. In many sections of the United States, automobiles can be run for several years without appreciable deposit of mud or scale. Rainwater or other so-called soft water should be used wherever possible, and all water should be strained.

34. Defective Pump Packing.—If the packing of the cooling-water circulating pump becomes loose enough to cause a leak, the water system will be gradually drained. When the water level falls below that necessary to keep up circulation, the cylinders will become hot, possibly hot enough to cause trouble in the engine.

The circulating pump is usually provided with an adjustable stuffingbox gland so as to keep the packing water-tight. If any special form of packing originally used in the pump becomes so worn that it cannot possibly be kept water-tight, the pump can be very satisfactorily packed by the use of tow, provided the gland is anything like the customary form. *Tow* is an inferior quality of flax, such as is used in making linen goods. In order to use the tow for packing, it should be straightened out into a rather thin, long string and then twisted slightly so as to hold it in shape. The ends should be tapered down to a few fibers. To put the tow packing in place, it is wrapped around the spindle and pressed into the stuffingbox space with the end of some blunt tool, such as a screwdriver that is worn round on the corners or a hardwood stick suitably shaped. The tool used should not have sharp edges, else it will cut the fiber of the tow. Care should be taken not to scratch a bearing surface or injure a screw thread with a hard steel tool. The gland of the box is then pressed into place and drawn down hard against the packing by the nuts or other devices provided for holding the gland in place. After the gland has been drawn down hard against the packing, the nuts should be slightly loosened to remove the pressure against the packing. The object in first tightening the gland up hard against the packing is to press the packing into shape, so that it will fill the packing space. The final adjustment should be such that the shaft will turn freely, but there should be no leak past the gland.

LUBRICATION TROUBLES

35. Lack of Cylinder Oil.—The symptoms of lack of cylinder oil are manifested in a sudden laboring of the engine, a dry or groaning sound, and partial loss of compression, followed by probable seizing of the piston. If the piston does not seize, it and the cylinder walls will at all events be scored. A groaning sound due to lack of lubrication in a cylinder practically never occurs in a single-cylinder engine, and it seldom occurs in one with only two cylinders; but in an engine with three or more cylinders, one of the cylinders may become dry and the others still have enough power to drag the dry piston against the excessive frictional resistance thus produced.

Among the causes of lack of cylinder oil are clogging of lubricator by dirt or waste, obstruction in oil pipes, leaky check-valves, leaky pump packing, broken oil pipe, oil too cold to feed, lack of oil in crank-case, etc. The remedies for trouble due to lack of cylinder oil will become obvious on inspection. The engine should be stopped and allowed to cool, and it should be seen that the section of the crank-case corresponding to the dry piston has a liberal supply of oil before starting again. Also, a little oil should be squirted through the compression relief cocks or through the hole made by removing a spark plug, in order to insure the lubrication of the pistons without waiting for oil to reach them from the regular sources. The obstruction should be removed or the break repaired as soon as possible.

36. Lack of Oil in Bearings.—A slightly loose main or crankpin bearing will sometimes be cut badly as a result of a temporary stoppage of oil feed, and yet give no noticeable symptom until the bearing is so badly cut that knocking begins. If a well-fitted bronze-bushed bearing becomes dry, it is more likely to stop, or at least retard, the engine. A babbitted bearing will melt out and let the shaft settle as far as other supports or bearings will allow. The result may be a violent pounding, a bent or broken shaft, or cut bearings generally, according to the particular conditions.

There is no real safeguard against lack of oil in bearings except the vigilance of the operator, combined with a system of oiling not liable to go wrong. It is not safe to depend on detecting a dry bearing by the sense of touch, because often the metal adjacent to bearings is sufficient to carry the heat away. Generally, trouble from this cause is due to neglect to supply oil or to see that the sight feeds are working properly. It may also be due to a broken pipe, cold oil, etc.

There is no excuse for neglect to clean the oil strainer or for failure to inspect the oil pipes, unions, etc. or to know when starting out how much oil is in the crank-case. A badly cut bearing should be sent to a repair shop and attended to without delay; but a bearing only slightly cut may be kept in service by the addition of a small quantity of flake graphite to the oil. If possible, the shaft should be taken out and polished with emery cloth and oil, otherwise bronze from the bearing is likely to cling to it and aggravate the cutting.

37. Improper Oil in Cylinders.—The trouble symptoms produced by the use of oil unsuited for lubricating the piston are white or yellow smoke in the exhaust, rapid fouling of spark plugs, partial clogging of inlet and exhaust valves, and rapid accumulation of carbon on the valves in the combustion chamber and about the piston rings.

To remedy the trouble, empty out all of the unsuitable oil if possible and substitute oil known to be good. Inject kerosene freely through the compression relief cocks or spark-plug holes to loosen the carbon deposit on the piston rings, and use kerosene to free the valves if they stick. Drain the crankcase, and if possible open it and clean out any carbon that may have worked down past the piston and mingled with the oil. Change all the spark plugs, and clean them when opportunity offers. Put in plenty of fresh oil before starting, and see that oil is supplied to the pistons so that they will not go dry before oil begins to feed from the cylinder lubricator.

38. Too Much Oil on Pistons.—Too much oil on the pistons is indicated by white smoke in the exhaust, and

fouled spark plugs and valves, substantially as when inferior oil is used, though the symptoms are not so pronounced. An examination of the combustion chamber through the inlet valve or spark-plug hole, using a mirror and electric flash-light if necessary, will show an unnecessary amount of oil around the top of the piston. With the oil correctly regulated, it should not accumulate on the piston head in any great quantity.

Trouble from this source is remedied by drawing off part or all of the oil from the crank-case, provided it contains more than is necessary for running the engine, and reducing the oil feeds to the cylinders if necessary.

CYLINDER AND PISTON DISORDERS

EXAMINATION OF PARTS

39. Scored and Leaky Cylinders.—One cause of scoring of the cylinder lies in the fact that the ends of the piston pin or wristpin when loose sometimes protrude through the hole, or bearing, in the piston. Some pins have their bearing in the piston itself, while others, being tightly secured in the piston, have their bearing in the upper end of the connecting-rod. No matter which construction is employed, the ends of the pins should never come in contact with the cylinder walls. The pin must by some absolutely positive method be kept in place.

Although a loose wristpin is often the cause of a scored cylinder, yet there are three other causes, resulting from imperfections of design or of machine work, to which scoring can be traced, namely, loose core sand, imperfectly fitted piston rings, and loosening of the pins that are sometimes used to prevent the piston rings from turning in the slots in the piston.

40. Trouble from loose core sand is due to sharp sand that usually comes from the cored passage connecting the crank-case with the inlet or pass-over port to the combustion cham-

ber of two-cycle engines. With cylinder castings properly pickled in dilute sulphuric acid to remove the sand, this trouble is not experienced; but with the method of cleaning castings by means of the sand blast, the cored passages are frequently neglected. Some two-cycle engines are provided with a removable plate over the inlet port for the purpose of permitting an examination to make sure that it contains no core sand to cause trouble.

If, in an engine of the two-cycle type, the scoring consists of several parallel marks on the side where the inlet port is located, it is safe to ascribe the trouble to sand. If the scoring is on the exhaust-port side, it is usually an indication of insufficient lubrication; as the hot exhaust gases pass out they burn the oil off that side of the piston and cylinder, the exhaust side of a two-cycle engine cylinder being always hotter than the inlet side. Scoring may occasionally be due to the presence in the cylinder of pieces of the porcelain insulation of spark plugs. Cylinders have been practically ruined through dropping into them the pin or nut that holds in place the spring on an inverted inlet valve.

The scoring of a cylinder may also be caused by a particle of hard carbon getting between the cylinder wall and the piston, or by a small particle of hard foreign substance being drawn in through a carbureter whose inlet is not protected by a screen. A scored cylinder naturally allows leakage past the piston, with consequent loss of power. If the groove is so large that considerable of the hot gas can escape into the crank-case, the latter will become unduly warm during the regular operation of the engine.

41. Leaky cylinders, particularly in two-cycle engines, render the wristpin, crankpin, and main-shaft bearings subject to excessive wear, because the heat of the gases that pass by the rings into the crank-case tends to burn up the oil and heat the bearings. If the engine is of the two-cycle type, the leaking products of combustion not only foul the fresh charge of gas so that it is not so explosive, but also reduce the quantity of each charge.

If, in an engine in which the inlet and exhaust valves are tight and there is no leaky gasket, it is found that the compression has become materially reduced, the trouble is probably caused by leaks from distorted, scored, or imperfect cylinders, the pistons or piston rings being worn considerably or stuck in the slots of the piston. The only remedy in such cases is to remove the pistons for examination.

If the cylinder is found to be out of round or scored, it will have to be rebored or reground and new pistons and rings will have to be fitted unless a new cylinder and piston can be obtained at a lower cost. If the rings are found to be rusted or stuck in the slots, they will have to be removed, even if to do so it is necessary to break them. They may have worn to such an extent that the openings at the points of parting are such as to allow a loss of pressure, the leaking charge passing either into the tight crank-case, if the engine is two-cycle, or into the atmosphere. If such leakage is not stopped, the heat of the escaping gases will burn the oil out of the crank-case, and the bearings will soon become badly worn and perhaps ruined.

42. Cracked Cylinders.—The result of overheating, due to the failure of the cooling system, as well as of the freezing of the water in the water-jacket, is a cracked cylinder. The effect of a cracked cylinder is generally an immediate loss of power and still more excessive heating of the cooling water, which, in the case of a single-cylinder engine, will generally result in stopping the engine. A multiple-cylinder engine, however, may continue to run on the other cylinders for some time after one has become cracked.

An engine that has a cracked, or porous, cylinder or a loose plug in a cylinder wall will always heat the cooling water more rapidly than when there is no such defect. Some of the cooling water will generally be drawn into the cracked cylinder during the suction stroke. This water immediately vaporizes, and the steam thus formed prevents a full charge from being drawn in during the suction stroke. The spark plug is also likely to become so wet that its insulation is

imperfect and a short circuit occurs. Both of these actions cause misfiring, and the dilution of the charge by the steam is liable to cause back firing into the carbureter.

A cracked automobile-engine cylinder can rarely be repaired satisfactorily in the ordinary garage or machine shop. There are a number of concerns, however, properly equipped to repair broken cylinders by brazing or welding, and in many cases such a concern can satisfactorily repair a broken cylinder at a small cost compared with the price of a new one.

43. Cylinder-Packing Troubles.—The joints between the cylinder head and the cylinder of automobile engines are kept tight by packings that are usually cut out of sheet asbestos about $\frac{1}{32}$ inch thick. When the packing is damaged by overheating or excessive pressure, water from the jacket leaks either to the outside or into the cylinder. The latter is the more serious leak of the two, as it interferes with the running of the engine by corroding the valve seats and stems, and preventing proper lubrication of the piston and cylinder.

In most cases, the blowing out of a packing is caused by the combustion pressure opening the joint between the packing surfaces, the packing being heated and partly destroyed, and allowing water to enter the combustion chamber. A partial or complete stoppage of the cooling-water supply or the clogging of the water spaces with lime or similar deposits will also result in the overheating of the cylinder and consequent damage to the packings.

As soon as a leak of water from a faulty packing develops, preparations should be made to renew the packing at the first opportunity. If the leak is to the outside, it may not interfere with the operation of the engine, although it will cause inconvenience through having to replenish frequently the water in the cooling system. If the leak is toward the combustion chamber, the engine will generally stop in a short time.

44. Most automobile engines have the cylinder heads and cylinders in one piece; but a few engines have copper or aluminum water-jackets. There are, however, some engines

with separate heads. In some cases, the cylinder heads, when separate, are made a ground fit on the cylinders, but they are commonly made tight by abestos gaskets. Leakage through these gaskets may be detected sometimes by the sound and sometimes by putting a little oil over the suspected place and noting the resulting bubbles when the crank is turned.

In case a cylinder-head gasket leaks, it will be necessary to put in a new gasket. The head should be taken off, the old gasket removed, and the iron surfaces in contact with it carefully scraped clean. The new gasket may be of sheet asbestos, and it should be sprinkled evenly with powdered graphite to prevent it from sticking. It may be cut to size by laying it on the cylinder and tapping it lightly with a small hammer to indicate the outlines. Care should be taken not to let inwardly projecting edges interfere with the valves; and, also, if there are openings through the head for the passage of water, it should be seen to that these are not closed by the asbestos.

A good packing for the cylinder heads is sheet asbestos with woven brass wire embedded in it. Packing of this kind is much stronger than ordinary sheet asbestos, and will not blow out unless the cylinder-head bolts are loose or the head is a bad fit. In replacing a cylinder head, the bolts should be tightened gradually and evenly, each being tightened a little at a time and the round being made three or four times so as to avoid localizing the stress on any one bolt.

There is, of course, but one remedy for leaky gaskets, namely, renewal. The old gasket should be carefully and completely removed, and by means of a straightedge a careful examination should be made to discover, if possible, why the gasket gave way at a particular point. There may have been insufficient surface or too little holding-down pressure to keep the packing in place, the studs may have been too far apart at the point of rupture, or the nuts may not have been tightened after the engine had become heated.

45. Worn Pistons.—The piston should be examined carefully for wear. The side on which the angular pressure

of the connecting-rod is exerted should, of course, show the most wear. If the front or the rear side of the piston shows wear at the top or the bottom, with a corresponding amount of wear on the opposite bottom or top, it is proof that the hole through the piston for the piston pin, to which is connected the upper end of the connecting-rod, is higher at the end showing wear at the top of the piston than at the end showing wear at the bottom. If this is found to be the case, and the wristpin is tightly secured in the piston, the connecting-rod bearing for the wristpin will be found to have worn badly and will be bell-mouthed; that is, larger at the ends than at the center. The remedy for this condition is to true up the hole carefully and bush it, or to use a pin that is a trifle larger than the hole, increasing the size of hole in the upper bushing slightly. This is a repair job that should be entrusted only to a thoroughly reliable machinist having the tools and means for doing accurate work. Side wear on the piston is much more likely to show in engines having the wristpin held securely in the upper end of the connecting-rod, the ends of the pin having bearings in the piston.

46. Worn and Broken Piston Rings.—Piston rings become stuck in the slots of the piston from two causes, namely, from water getting into the combustion chamber, causing the rings to rust, and from the sides of the slots being slightly tapered instead of parallel. Where tapered sides are found, it is usually necessary to straighten them up in a lathe and use slightly wider rings. Piston rings should be renewed much oftener than is customary. As they become more and more open at the ends, the hot gases passing by the ends of the rings have a harmful effect on the polished cylinder surfaces, and in two-cycle engines they foul the mixture in the crank-case.

Broken piston rings, particularly in engines with ports that are opened and closed by the pistons, are a source of annoyance and frequently cause much trouble. Piston rings are frequently broken because of insufficient care in putting the piston, with the rings in place, into the cylinder, but breakage

is more likely to result from getting a ring end caught in a port. To prevent this, two-cycle engine rings are usually pinned so that they cannot turn until the ends get opposite the port.

The breaking of a piston ring will cause loss of compression, which may be distinguished from leakage due to the rings being worn by the fact that the broken ring will make a distinct clicking sound at the end of every stroke. It will also be found that oil squirted on the piston when a ring is broken will not stop the leak. If the engine has more than one cylinder, it is probable that loss of compression due to lack of oil will affect all the cylinders, whereas a broken ring affects one only. If a piston ring is broken, it becomes necessary to take off the cylinder without delay and to put in a new ring.

47. Piston rings are sometimes held in position by small pins, one in each ring, so that the joints of adjacent rings are diametrically opposite. If for any reason these pins break, a ring may slip round until its joint is in line with that of the next ring above or below. With badly worn rings gaping wide open at their ends, this condition will cause loss of compression that may be very puzzling. It is an unusual occurrence, however, and in order to locate the trouble, the cylinder may have to be taken off.

48. A loose piston ring, when the looseness is sidewise in the grooves, is liable to produce a very sharp clicking noise. This noise may not occur to a noticeable extent when the engine is well lubricated or running on a light load; but when the throttle is opened, the clicking may be very decided, especially if the cylinder is not amply lubricated.

No special injury is likely to occur on account of clicking piston rings, but the gradual wear of the sides of the rings and the grooves in which they fit will have a tendency to force them out against the cylinder wall harder than is necessary for satisfactory operation. If the rings are allowed to operate in this manner for a great length of time, it is possible that this wear may be so uneven that, together with the increased pressure against the cylinder wall, a ring may be broken. In

breaking, a ring sometimes gives off a small piece of metal that scores the cylinder.

The remedy for worn slots and rings is to remove the rings, and if the sides of the grooves in which they fit are found to be worn, the grooves should be machined in a lathe so as to make them of uniform width. After this, new rings of the proper width should be inserted.

TESTS FOR COMPRESSION LEAKS

49. Hand Tests.—For a four-cycle automobile engine with the usual mechanically operated valves of the poppet type, a hand test for compression can be made by cranking the car slowly by hand and noting the resistance to the rotation that is caused by the action of the compressed charge upon the piston. Before making the compression test in this manner, however, it should be first determined how freely the engine rotates when there is no compression. This can be done either by opening the compression relief valves of all the cylinders or by removing the spark plugs, releasing the clutch, and then cranking the engine at a comparatively slow rate by hand. An engine that is in good condition can generally be rotated slowly by the pressure of one finger of the hand on the hand crank. If the engine does not rotate as easily as this, there is too great frictional resistance to its rotation, except, of course, in possible cases of an exceedingly large engine. If this frictional resistance is very great, it will probably not be possible to make the compression test before the engine is put in proper condition with regard to its ease of rotation.

50. The following is a general outline of the method that can be employed to test the compression by cranking the engine:

Open the relief valves or remove the spark plugs of all cylinders, and then open the ignition circuit for all cylinders at the switch provided for that purpose or at each spark plug.

Crank the engine slowly to determine whether or not it rotates freely and without excessive frictional resistance. If there is great frictional resistance, the engine should be lubricated to reduce the friction. If there is no reduction of friction by complete lubrication, then the crank, cylinders, and pistons should be examined to determine their condition. Next close the relief valve of one cylinder, or insert the spark plug if it has been removed, and rotate slowly until the compression resistance begins to be felt. If the compression is good, the crank can be rocked back and forth by pulling it up well toward the dead-center position and then reducing the pull on the hand crank to allow it to be moved backwards by the action of the compressed charge on the piston. When all the parts are as nearly air-tight as they should be for proper operation of the engine, this rocking of the crank against compression can be continued for some time.

Another method is to pull the crank around until the compression resistance is felt to a considerable extent, and then to hold the crank stationary and note whether the compression resistance continues or decreases. By holding the crank in different positions, corresponding to a greater or a smaller degree of compression, the tightness of the piston rings in the cylinder can be tested for different positions of the piston. This, of course, can be done only when the compression space is tightly closed at all other places; that is, when there are no leaks except possibly that at the piston.

51. If the compression is poor, it may be due to a leak at any of the following parts: The exhaust valve, the inlet valve, the spark plug, a relief valve that is partly open or loose, the piston, or the joint between the cylinder or cylinder head when the head is a separate part from the cylinder barrel. It may also be due to a leaky plug that closes an opening between the bore of the cylinder and the water-jacket space, porous metal in the cylinder wall, a cracked cylinder, or a cracked piston head.

52. To test for leaks around or in spark plugs, put cylinder oil or kerosene around the spark plug, crank the engine, and

note whether bubbles appear in the oil around the spark plug. The appearance of bubbles in this place indicates leakage around the spark plug. A spark plug may leak between its insulation and the metal parts. Kerosene should be used in testing for such a leak. The relief valve and plugs over valves can be tested in the same manner as the spark plug.

53. A test for leaky valves may begin at the exhaust valves. In making this test, twist the valve around so that it has a rotary, or grinding, motion on its seat. By turning the crank-shaft to the position in which the valve cam just begins to lift the valve from its seat, the lifting pressure of the push rod makes it possible to twist the valve around more easily. Twisting the valve can sometimes be done with the fingers, but generally a pair of gas-pipe pliers or some similar tool is required. Twisting the valve around on its seat will generally remove foreign matter, such as a particle of carbon, from between the valve and its seat. Carbon in this location of course causes leakage at the valve. Note whether there is a small space about the thickness of a visiting or business card between the end of the valve stem and its lifter. There should be such a space.

If necessary, remove the exhaust pipe or manifold and hold a lighted candle or match at the exhaust opening of the cylinder under test. If there is much leakage past the exhaust valve, the flame will be blown outwards by the current of escaping air or gas. It is best to cut off the supply of gasoline while making this test, so that there can be no ignition.

If the exhaust valve opens downwards from its seat, as in some engines, cylinder oil may be put around the valve just above the point where it bears on its seat. Leakage will then be indicated by bubbles or by the oil being blown off. A fine powder, such as talcum powder, can sometimes be used instead of oil. To test for a cracked valve, put the oil or the powder over the entire valve and look for bubbles or blowing off of the oil or powder while the engine is in compression.

Next, put a blank gasket over the exhaust opening so as to prevent any air or gas from passing out of it. This gasket

may be clamped between the cylinder outlet and the exhaust pipe. Put oil around the valve stem where it emerges from its guide, crank the engine against compression, and note whether bubbles are formed in the oil. A heavy oil such as that used in some steam-engine cylinders will be found suitable for this test. If a piece of sheet rubber is used for the blank gasket and is held in place by an open ring of some thick material, the rubber will be bulged out by the pressure of air escaping past the exhaust valve, provided the valve stem is not very loose in its guide. If the stem is loose in its guide, a liberal supply of heavy oil or thin grease may prevent leakage past the stem during this test.

To test further for a crack in the valve, the valve should be removed. If the valve is slightly raised around the edge, immerse it partly in gasoline with the raised edge upwards. The gasoline will penetrate even a very small crack and appear on the upper side of the valve. It may sometimes be more convenient to pour gasoline on the depressed upper surface of the valve and then note whether it appears on the under surface.

The inlet valve can be tested in the same manner as the exhaust valve.

54. To test for a leaky cylinder, remove the pipe through which the hot cooling water flows from the cylinder jacket and see that the jacket is filled to the top of the outlet. Crank the engine against compression, and look for bubbles rising through the jacket water. Such bubbles indicate a leak from the cylinder bore into the jacket space. It may be possible that the bubbles come from around a plug in the cylinder wall that was inserted to close a blowhole; otherwise, bubbles indicate a cracked or porous cylinder wall in an engine whose cylinder head is integral with the barrel. If the cylinder head is separate from the barrel, the leak may be through the joint between these two parts.

55. To test for leakage past the piston in an engine of the vertical type with the cylinders above the crank-shaft, pour enough kerosene into the cylinder to cover the top of the

piston completely. Crank the engine, hold it on compression, and note whether or not any of the kerosene drips down past the piston. The crank-case will have to be open, of course, for this test. Gasoline should not be used in the cylinder, however, because it will penetrate a joint between the piston rings and cylinder wall that is sufficiently air-tight for all practical purposes. Moreover, if gasoline is used, it will cut the oil so thoroughly from the rubbing surfaces that there is danger of their abrading and scoring when the engine is run. It may be possible to observe whether the kerosene leaks out between the piston and cylinder wall or through a crack in the piston head. In the latter case, the kerosene will come down through the inside of the piston.

56. To determine whether or not the piston itself is cracked, it should be removed from the engine and partly immersed in gasoline, keeping the open end on top. If it is cracked, the gasoline will penetrate to the inside. Another method is to pour some gasoline into the piston while it is placed with its open end facing upwards and then note whether or not any gasoline penetrates through a crack to the outside.

57. Running Test for Cylinder Leaks.—Instead of testing by hand cranking, it is sometimes more convenient to examine cylinders for all leaks except valve leaks while the engine is running.

For leaks past the piston or through a crack in the piston head, open the crank-case, jack up the rear wheels so that they are free to rotate, and start the engine. Put the friction clutch in engagement and apply the brake so as to make the engine pull up to about its full capacity. Note whether smoke appears in the crank-case. The presence of smoke in this place is due to a leak past the piston or through a crack in the piston head. If the mixture is made overrich, more smoke will appear in the case of a leak than with a normal or lean mixture. An excess of lubricating oil may produce more smoke in the crank-case than will less oil, especially if the oil is very thin and of a poor quality for cylinder lubrication. There is always a possibility, however, that an excess of lubri-

cating oil will stop a leak past the piston and thus prevent the escape of smoke in the crank-case.

58. To test for a cracked or porous cylinder, a loose plug in the cylinder wall, or leaks between the head and the barrel of the cylinder, provided these parts are separate members of the engine, proceed as follows: Remove the cooling-water pipe from the top of the cylinder, disconnect the water-circulating pump so that it will not run, fill the water-jacket until the water is level with the top of the outlet, and jack up the rear wheels of the car. Start the engine, immediately put the clutch into engagement, and apply the brakes so as to put nearly the full load on the engine. Notice whether bubbles of gas rise through the cooling water. If the vibration of the engine agitates the water so that it is difficult or impossible to determine whether bubbles are rising through it, place a piece of window glass over the opening so as to be in contact with the surface of the water and thus keep it quiet.

It is not generally possible to determine where the gas escapes from the cylinder while making this test unless there is an unusually large opening in the top of the jacket for the outflow of the cooling water. This test must be made rather quickly, because the heating of the engine will soon cause bubbles of air to appear on the outside of the cylinder walls. These bubbles finally detach themselves and rise to the top of the water. Continued heating of the cylinder may be sufficient to produce steam in the cooling water, and this steam will rise in the form of bubbles to the surface of the water. It sometimes happens that a cracked cylinder or a leaky plug does not leak while the engine is cold, but begins to leak freely after it is well warmed up. The engine should therefore be run long enough to heat it well without allowing it to become so hot as to generate steam. In some cases it may be possible, without great trouble, to arrange for a slow circulation of water through the cooling jacket.

59. Hydrostatic Test for Cylinder Leaks.—A single test for all leaks from the cylinder of an engine can be made by filling the cylinder with liquid under pressure.

Kerosene is doubtless the best liquid for this purpose, although water answers fairly well. Water does not pass between oily surfaces so readily as does kerosene and for this reason does not show minute leaks so well, except, of course, where there is no oil. A small force pump capable of giving a pressure up to 350 pounds per square inch is required.

The hydrostatic test can be made in the following manner: Disconnect the mixture inlet pipe, the exhaust pipe, and the cooling-water inlet pipe, and stop them up with a cork or a plug of some kind. Remove the spark plug, and attach the force pump to the cylinder by means of a pipe connected to the opening left by the removal of the spark plug. Pump the kerosene or the water into the cylinder and look for leaks. The leaks will be indicated by the flow of the liquid from them.

If the crank-shaft is left free to rotate as the pressure is applied to one cylinder only, the piston will naturally move out to its position farthest from the cylinder head. This position is the one in which the gas pressure applied to the piston is lowest in the regular operation of the engine, and also the one in which leaks at the piston are of least importance. A pressure of 60 pounds per square inch is high enough for testing in this position.

The test for the piston in the position farthest from the crank-shaft can be made by placing the crank-shaft in the head-end dead-center position for the cylinder under test and locking it in this position. This can generally be done by throwing the clutch into engagement and setting the brakes, provided the crank-shaft is placed accurately in the head-end dead-center position. A pressure of about 350 pounds per square inch may be applied while the crank-shaft is in this position. The piston can be put in different positions and the flywheel locked to hold it while pressure is applied with an intensity corresponding to that which occurs during the operation of the engine.

60. Compressed-Air Test for Cylinder Leaks. If compressed air is available, it may be used for testing in a manner similar to that described in the preceding article. It

should be borne in mind, however, that compressed air is very expansible and is therefore liable to produce violent motion of the engine if the parts are not locked securely.

If the cylinder is removed from the car and immersed in water during the application of compressed air, the leaks will be plainly indicated by the bubbles coming from them. The piston must be held in the cylinder by some means after it is removed from the car, as, for instance, by a block of wood held against the piston by bolts and clamps suitably arranged. A metal clamp should not be used against the edge of the piston.

VALVE-GEAR DERANGEMENTS

VALVE TROUBLES

61. Leaky Inlet and Exhaust Valves.—Trouble from loss of compression in the combustion chamber, when the spark plug is tight and there is plenty of oil on the piston, is generally due to leaky valves. In order to determine whether the leak is in the valves or in the piston rings, a moderate quantity of oil may be squirted through the compression relief cocks and the crank turned two or three times, so as to check temporarily whatever leakage there may be around the piston. If the compressed charge still escapes, the inlet valve, if located over the exhaust valve, may be taken out and examined. The leak, however, is more likely to be in the exhaust valve, because the seat of the latter is subjected to the eroding action of the highly heated exhaust gases that pass over it.

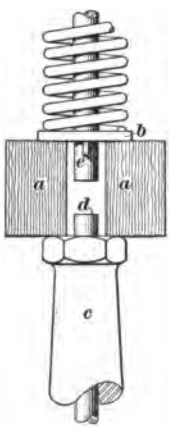


FIG. 2

To take out the exhaust valve, turn the engine over by hand, with the switch off and the compression relief cocks open, until the valve is opened. Then prop up the valve spring with two pieces of wood or brass *a*, Fig. 2, cut to

the proper length to fit between the spring collar *b* and the upper end (or lower end, if this is more convenient) of the push-rod guide *c*, and turn the engine again until the push rod *d* is down as far as it will go. Push the exhaust valve down; the key at *e* may now be slipped out. If the props have been made accurately to length, the valve may be slipped up and out, leaving the spring and the collar in place. Inspection should show the valve seat to be dull—not glossy—and of uniform appearance all the way around. If the seat of either valve is pitted or rough, or if it is worn bright on one side, showing that it has been seating only on that side, it should be reground.

62. If blocks cannot be placed on the end of the valve-lifter guide in the manner just described, it may be necessary to use a tool, called a **valve lifter,** made especially for the purpose of lifting valve springs. There are several styles of valve lifter on the market.

One form of tool for compressing a valve spring so that the key, or pin, can be removed from the stem is shown in Fig. 3. This tool has a hook-shaped member *a* to which is attached a piece of chain for supporting the lever that is used to compress the valve spring. In engines designed with valve covers that are depressed in the middle, the hook can be placed in the depression of the valve cap over the valve, and in other cases it can be placed against the top of the valve itself when the valve cap is removed.

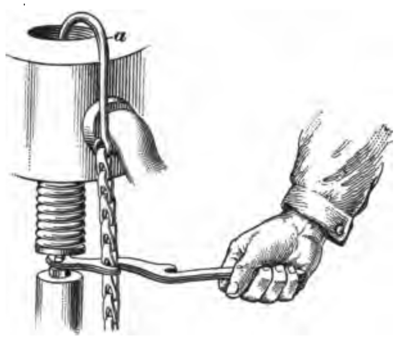


FIG. 3

A similar device can be made out of a strong string or a piece of wire and a lever with a suitable end for engaging the spring, for instance, a long screwdriver. The string or the wire is formed into a loop, and one end of it is fastened somewhere near the top, or head, of the valve. The lever is passed

through the other end of the loop, which acts as the fulcrum for the lever. Pressing down on the outer end of the lever will force the valve spring upwards.

63. Another tool for compressing the valve spring in order to remove the key from the valve stem is shown in Fig. 4. The two pronged ends *a* and *b* are inserted between the thrust washer against which the valve spring bears and the guide of the valve lifter rod or some corresponding part. Before inserting the two prongs, however, they are brought together so as to allow easy insertion. The prongs are then separated by turning the wing nut *c*. Screwing up this nut draws the screw *d* back in the direction away from the prongs.

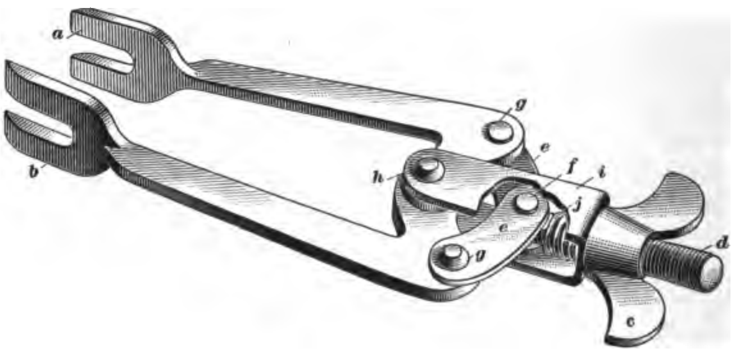


Fig. 4

The inner end of this screw is attached to togglejoint links *e* by means of a pin *f*. The outer ends of the links are connected by means of pins *g* to the arms that carry the prongs. The arms are pinned together by the pin *h*, which also pins them to the **U**-shaped piece *i*, against which the nut *c* bears. The expansion spring *j* forces the threaded piece *d* in toward the togglejoint when the wing nut is unscrewed, thus bringing the prongs toward each other.

64. A leaky exhaust valve is generally due to warping or pitting of the valve; the valve seat rarely pits. The pitting is especially likely to occur if the engine is run with the ignition later than it should be. When running in this man-

ner, the hot gases or even the burning gases raise the temperature of the valve to a high degree. This high temperature and probably the erosive action of the hot gas flowing past the valve cause the pitting. If a pit extends all the way across the bearing surface of the valve, or if two or more pits connect with each other so as to reach across the bearing surface, which is usually the case, the valve will, of course, leak. An extremely small pit in a valve will cause enough leakage to cut down the power developed in the corresponding cylinder to a very small proportion of what it is under proper operating conditions.

The remedy for a leaky valve is to regrind it properly.

65. A bent valve stem may cause the valve to leak by preventing it from seating properly. Such a stem may also bind in its guide, so that the valve remains quite wide open at times, but closes more or less perfectly at other times.

A valve stem that is too long will also cause a valve to leak. After regrinding a valve and drawing out the stem, the latter may be so long as to strike its push rod or lifter so that the valve cannot rest on its seat. A stem that is just long enough to allow the valve to seat itself and give good compression when the engine is cold may be expanded enough by the heat when the engine is running to prevent the valve from settling on its seat and thus cause leakage that materially cuts down the power of the engine.

A dirt-coated valve stem may cause the valve to behave in much the same manner as a bent stem, except that there is not likely to be any leakage when the valve is resting on its seat. It should always be remembered that a particle of carbon or other foreign matter may cause a valve to leak temporarily. A dirt-coated valve stem can sometimes be cleaned by putting kerosene on it while the engine is hot. If the engine is cold, gasoline will answer as well or perhaps better. The gasoline is useless for this purpose when the engine is hot, because under such conditions it immediately vaporizes and passes off. In some cases, however, the coating is of carbon so hard that neither the kerosene nor the gasoline will remove it. Prob-

ably the only remedy in such a case is to scrape off the carbon with a suitable tool.

66. Excessive Lift of Automatic Inlet Valve.—The lift of an automatic inlet valve should be proportionate to the spring tension and to the weight of the valve, so that the spring will be able to overcome the inertia of the valve and close the valve before the piston has started so far on its compression stroke as to expel any of the mixture through the open valve.

The symptoms of too great a valve lift are loss of power and blowing back at high speeds. A valve 2 inches in outer diameter should not ordinarily lift more than $\frac{1}{8}$ inch, and a lift of $\frac{3}{16}$ inch would be excessive for almost any valve found on high-speed engines. An excessive lift, like a weak spring, is likely to result in breakage of the valve stems and keys through unnecessary hammering of the valve when opening and closing.

67. Broken Inlet-Valve Stem or Key.—Trouble from a broken inlet-valve stem or key is more likely to occur with automatic valves than with valves mechanically operated. The result, if the valve opens downwards, is to let it stay open all the time, causing that cylinder to cease work, while the sparks from the plug ignite the mixture in the intake pipe and cause explosions there and in the carbureter. If the valve, whether automatic or mechanically operated, opens upwards, it will clatter on its seat and permit much of the mixture to be expelled during the first part of the compression stroke.

68. Broken Exhaust-Valve Stem or Key.—As there is nothing to prevent the valve from being sucked wide open on the suction stroke, an accident of this kind will generally cause that cylinder to go out of action entirely. The clattering, if the engine continues to run by virtue of other cylinders, is likely to be marked.

VALVE-SPRING DEFECTS

69. Weak or Broken Inlet-Valve Spring.—Sometimes the inlet-valve spring, especially if the valve is of the automatic variety, will weaken from becoming overheated. In time, a spring loaded too near its elastic limit will break from the jarring to which it is subjected. The symptoms in either case are loss of power at high speeds—although the power may still be ample at low speeds—and clattering of the valve and blowing back in the intake pipe at high speeds. The latter trouble may easily be detected in a single- or double-cylinder engine by holding the fingers close to the air intake, when the backward puffing will be very perceptible. If the engine has four cylinders, it may be possible for the inlet-valve springs to be slightly weak without the mixture blowing back into the intake, owing to the fact that one or another cylinder is aspirating all the time and the air expelled from one cylinder is drawn into the next. One way to get around this difficulty is to block open the exhaust valves of two cylinders—the first and fourth or the second and third—while the others are tested. It will probably be simpler, however, to experiment with the valve-spring tension. If the valve spring is weak, and if it is temporarily increased in stiffness by putting washers under it to compress it, a marked increase in the power of the engine at high speeds will be noticeable. Care must be taken not to use so many washers that the valve cannot open. The proper remedy, however, is to put in a new spring; or, if this cannot be done, to stretch the old spring. For a valve lift of $\frac{1}{8}$ inch, and for average engine speeds, the tension should not be less than 1 pound per ounce weight of the valve, washer, and key. The engine will work better if the springs are a little too stiff than if they are not stiff enough. There will also be less danger of breakage of the valve stems and keys.

70. Weak or Broken Exhaust-Valve Spring.—Owing to the heat to which it is subjected, the exhaust-valve spring is more likely to weaken than the inlet-valve spring. The

symptoms are loss of power, owing to the valve lingering open at the end of the exhaust stroke, and clattering when the valve closes.

71. Unequal Tension of Automatic Inlet-Valve Springs.—The effect of unequal tension in the springs of automatic inlet valves is to permit one cylinder to take more gas than another. Consequently, at slow speeds the cylinder whose valve spring is weak will get the larger charge, and at high speeds part of the charge will be blown back through the valve whose spring is weak, so that the other cylinders will get stronger impulses. A quick way to test the equality of valve-spring tension without taking out the valves is to run the engine slowly with the throttle almost closed. This will cause the cylinders whose springs are stiffer to receive scarcely any gas, and the cylinders whose valve springs are weak will do most of the work. It is possible, however, to go to excess in a test of this sort, because, when an engine is running light with the minimum quantity of gas, one cylinder is almost sure to get more gas than another, provided the inlet valves are automatic, even with the most careful equalizing of the springs. If the tension of the valve springs is under suspicion, the valves should be taken out and the springs tested by pressing the valve stems together, as illustrated in Fig. 5. If the springs are unequal in strength, the weaker one will be compressed more than the other.

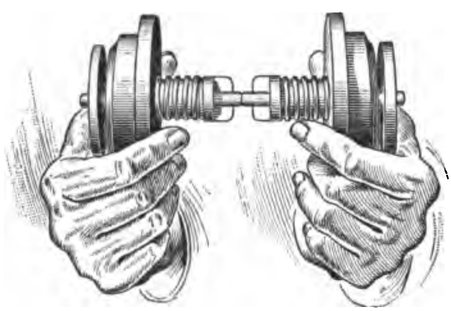


Fig. 5

72. Temporary Repair of a Broken Valve Spring. A broken valve spring of the coiled-wire type can sometimes be temporarily repaired by placing a metal washer, such as is used on bolts, between the two ends of the broken spring.

This washer, of course, may be of some other material than metal, as, for instance, hard fiber or wood. A better repair can sometimes be made by using a rather thin metal washer, slitting it radially inwards from the edges and then bending each second strip thus cut upwards and the other strips downwards, so that a sort of double cup-shaped piece is formed that will hold the ends of the spring in place better, if of the proper diameter, than will a plain washer. Sometimes two curved pieces of clock spring or corset steel can be used effectively for temporarily replacing a broken spring of an automatic inlet valve. As shown in Fig. 6, the two pieces of steel are tied to the key that passes through the end of the stem. For tying, soft wire or even string may be used, as there is nothing to burn the string, unless there is back firing. The upper end of each piece of steel must be notched to fit over the arms *a* of the valve-stem guide. Such a device is advisable only in an emergency, however.

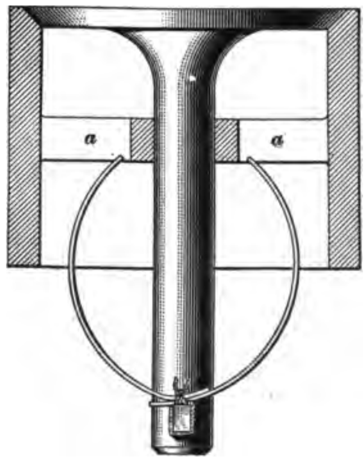


FIG. 6

DRIVING A CAR WITH A USELESS CYLINDER

73. If the inlet valve of one of the cylinders of a multi-cylinder engine becomes inoperative, that cylinder, of course, is useless for driving the car. The car, however, can be run on the remaining cylinders, but in order to do so, it may be necessary to close the inlet port in some manner. This can generally be done most conveniently at the inlet valve, provided it is not broken, by holding the valve firmly and permanently against its seat.

If the valve is mechanically operated, the means of lifting it must first be removed, provided the stem is still intact.

In some engines, the push rod is the easiest to remove, and, of course, after this is done the valve will not be mechanically lifted. In case this rod cannot be removed, it may be necessary to cut off the valve stem. The valve can then be held in place by inserting a block of wood between it and the cover, or cap, that closes the opening through which the valve is inserted and removed. The block of wood should be thick enough to press hard against the valve before the cap has been drawn down tight into its ordinary position for closing the opening. Although there is really no need of doing anything with the exhaust valve, yet it may be advisable to block this valve also in order to prevent the drawing of dirt and scale into the cylinder from the exhaust passage. If the exhaust valve is blocked down, the means of lifting it will, of course, have to be removed.

If the inlet valve is automatic and is located opposite the exhaust valve, both of them can be held permanently closed by placing a block between them and tightening down the cap that holds the inlet valve in place. The means of lifting the exhaust valve must of course be removed.

If the exhaust valve is the one that is broken, it is generally advisable to block down the inlet valve, and, if convenient, the exhaust valve also. In case a valve is broken so badly that it cannot be used for closing the port permanently, a block of wood can be shaped so as to fit into one or both ports, as the case may be, and then fastened in place in the manner already described.

The closing of the inlet port prevents the forcing of burned gases from the disabled cylinder into the inlet pipe and carbureter, and thus permits the remaining cylinders to act satisfactorily. When a disabled cylinder is thus cut off from communication with the inlet pipe, the remaining cylinders will operate in the usual manner and the disabled cylinder will require very little power to drag it. It may be advisable in some cases to remove the spark plug, especially if the exhaust valve is not blocked down. The removal of the spark plug will prevent to some extent the drawing of exhaust gases into the disabled cylinder.

MISCELLANEOUS TROUBLES

MUFFLER AND EXHAUST-PIPE TROUBLES

74. The habitual feeding of an excess of lubricating oil to the engine or the use of an overrich mixture will gradually clog the muffler with a mixture of carbon and half-burned oil, or loose carbon, which will reduce the power of the engine by creating a back pressure that is above the normal.

The symptoms produced are abnormal heating of the exhaust pipe as well as loss of power and inability to speed up the engine when the mixture, compression, valve timing, and ignition are known to be good. If the exhaust pipe can be disconnected and the engine gives its full power at once, it is an infallible indication that either the exhaust pipe or the muffler, or both, are choked.

The obvious remedy for a choked muffler is to clear it. In some cases, when the deposit consists of fairly loose carbon, it may be knocked loose by striking light, sharp, blows on the muffler shell with a stick of wood. The exhaust will then blow most of the loose carbon from the muffler. If half-burned oil is present, the carbon deposit will be very tenacious. The muffler must then be taken apart for cleaning. The carbon deposit can be softened by a liberal application of kerosene and then removed by scraping.

75. A very hot exhaust pipe may be due to a clogged muffler or to the ignition being too late in one or all of the cylinders. If the ignition is not synchronous, then it should be brought into synchronism, so that there will be no reason for late ignition in any of the cylinders.

FUEL-SUPPLY DERANGEMENTS

76. Symptoms of Fuel Exhaustion.—When the fuel supply in the fuel tank becomes low, the engine will uniformly, but quite rapidly, lose power and stop. The length of time

required for this to occur depends of course on how much power the engine is called on to develop at the time. If the car is running along a smooth, level road it may take nearly a minute to exhaust the fuel from the carbureter, but if the engine is climbing a hill, the power may be completely lost in a few seconds after the fuel tank becomes dry.

In some forms of fuel tank, especially in a gravity tank with a nearly level bottom, the behavior of the engine may be somewhat erratic if the car is running around sharp curves or on the side of a road whose surface is considerably crowned. While running near the center of a crowned road, only enough fuel may reach the carbureter to keep the engine developing a part of its power. When the car is run to the side of the road, which brings the gasoline over the outlet of the fuel tank, or when it turns a curve so as to produce the same effect on the gasoline, the carbureter will receive a full supply of gasoline for awhile and the engine will develop full power. When a curve is turned in the opposite direction, however, or when the car is run back to either the level part of the roadbed or the other side of the crowned surface, it may lose power rapidly and then stop.

Many modern gasoline tanks are fitted with a small compartment in which from 1 to 3 gallons of gasoline is kept in reserve. Communication between the main and reserve compartment is ordinarily closed. However, on the fuel in the main compartment giving out, thereby giving warning of the near exhaustion of the gasoline supply, the reserve compartment can be readily brought into action.

77. Effect of a Clogged Vent Hole.—If the vent in a gravity fuel tank is clogged and the tank otherwise tightly closed, the engine may lose power very gradually and finally stop. The car generally stops when demand for more power is made upon the engine, as when starting up a hill. The length of time required to bring the engine to a stop depends on the amount of air space above the gasoline in the tank. If the tank is nearly full of gasoline, it will not take many minutes for the effect of the partial vacuum in the tank to

make itself evident by the decreasing power of the engine. On the other hand, if the tank is nearly empty, the car may run for an hour or so without any very great decrease in the power of the engine.

If the vent is only partly closed, or if the tank is otherwise not completely sealed, the partial vacuum in the tank can be reduced by permitting the car to stand for a short time. It may then be run again with entire satisfaction until the partial vacuum becomes great enough to prevent a sufficiently rapid flow of the gasoline from the fuel tank to the carbureter.

78. Effect of Water in the Gasoline.—If, when filling the fuel tank, the fuel is always poured through a chamois-skin strainer, troubles from water in the gasoline will rarely be encountered. However, should water get into the fuel tank, either through carelessness in washing the car or through failure to strain the fuel supply, it will almost immediately stop the engine when it reaches the carbureter and is drawn out through the spray nozzle. If only a few drops of water are drawn through the spray nozzle at a time, the engine may not be stopped, because the momentum of the moving parts may be sufficient to keep it running. Its failure to develop power while receiving water from the carbureter, however, is very evident. If considerable water gets into the carbureter, so that only water can be drawn from the spray nozzle for some time, then the engine will, of course, stop.

The bottoms of some fuel tanks are formed so that the water in the gasoline will lie in a portion lower than the outlet to the carbureter. But when the car swings around a curve, or possibly when it is climbing or descending a hill or is running on the side of a crowned roadway, some of the water may flow down to the carbureter. After the trouble caused by the portion of the water that flows to the carbureter in this manner has been overcome, it may occur again under similar conditions of movement of the car. This fault is probably one of the most puzzling and troublesome to detect and overcome, especially if there is no way of draining the water from the fuel tank, as is usually the case.

79. Temporary Repair of Broken Gasoline Pipe. If the gasoline pipe that conveys the fuel from the tank to the carbureter should break while on the road, a temporary repair may be made by slipping a piece of rubber hose over the broken ends. If no hose is at hand, the break may be repaired by wrapping ordinary cotton tape, such as is used by dressmakers, around it, and saturating the tape liberally with shellac varnish. The varnish should be put on while wrapping the tape. If the pipe is not completely broken in two, a liberal supply of cake soap wrapped over with tape will generally stop the leak for a time. If there is only a slight crack in the gasoline pipe, a piece of cotton wrapping cord will also generally be effective. This cord should be either saturated with shellac varnish while it is being put on or coated with soap before it is put on. Friction tape coated with adhesive rubber compound should not be used in places where gasoline can come in contact with it, as the gasoline will quickly dissolve the rubber compound.

TROUBLES FROM LOOSE OR BROKEN PARTS

80. Broken or Missing Part Between Engine and Driving Wheels.—If the engine runs but will not drive the car it is evidently because some portion of the power transmission system is either broken or lost. A systematic investigation will usually disclose the trouble. A key or pin of some portion of the transmission machinery may be lost. In some designs, this is a frequent occurrence in the universal joints that connect either the engine and change-speed gears or the change-speed gears and the rear axle.

81. Loose Flywheels.—A flywheel with a key that does not completely fill the keyway will generally give evidence of its looseness while the engine is pulling hard, especially if running at rather slow speed, by a heavy knocking or pounding sound. If the flywheel is very loose on the shaft and has considerable motion, its looseness can of course be readily detected; but if the flywheel fits fairly tight upon its shaft

and also has very little rotative motion on account of the loose key, the trouble is not so easy to locate. In order to determine whether the flywheel is loose, lock the crank-shaft of the engine so that it cannot move at all and then pull back and forth on the flywheel to see whether there is any rotative motion. It may be even necessary to remove the flywheel and test the fit of the key. If the key is loose, of course a new one that fits properly should be substituted.

82. Loose Bearings.—If a connecting-rod or crank-shaft bearing is very loose, it will invariably give rise to knocking or pounding. In some cases this looseness is sidewise (in a direction parallel to the axis of the journal). Side looseness will sometimes cause sharp knocking, although it may occasionally be rather heavy and dull in spite of the fact that the cylindrical parts of the journal and the bearing fit as snugly together as they should for proper operation. A ball bearing that has become worn more than is allowable in good practice will generally pound or knock, but the sound is ordinarily not so sharp as in the case of plain bearings.

If a bearing is very loose, it can of course be readily detected by taking hold of the parts and moving them back and forth or shaking them. However, when not great, it may not be easy to locate looseness. In the case of a connecting-rod, looseness can generally be located by holding the finger so as to press on both the connecting-rod and crank-shaft and then rocking the crank-shaft back and forth very slightly.

A slightly loose bearing on the crank-shaft can be easily detected by placing a block of wood or iron so that the crank when rotated will strike against it and thus prevent further rotation. By holding the finger on the crank-shaft and bearing and gently rocking the crank-shaft so as to make its throw strike the block gently, the looseness will generally be apparent by motion between the journal and the box of the bearing.

83. Loose Fastening Devices.—A loose bolt or other similar device used to fasten the engine to the frame of the car or even to fasten parts of the car frame together

will sometimes cause a loud knocking noise that may very easily be mistaken for a loose bearing in the engine or other parts of the car. The car should therefore be frequently examined for such loose parts.

CHAIN TROUBLES

84. Broken Transmission Chain.—If a driving chain breaks while on the road, a repair that will last until some place is reached where a permanent repair can be made can sometimes be effected with a piece of wire. Whether or not wire can be used, however, depends very much on the form of the chain and the nature of the break. Ordinarily, the method of using a wire is to wind it into the chain in place of the broken link, so that several strands of the wire occupy a position practically the same as that which was occupied by the broken link. For this use, as well as for other purposes, it is advisable to carry in the repair kit of an automobile a small coil of strong steel wire that is moderately soft (not so hard as spring wire). A wire about as large as that used in a moderate-sized hat pin is the most suitable for general use.

85. Adjusting of Transmission Chains.—If two chains are used, as is the case with side-chain drives in which each traction road wheel is driven by its own chain, it is very essential that the rear axle be adjusted so as to be parallel with the differential shaft that carries the driving sprockets for the transmission chains. This adjustment is made by means of the nuts and threads on the radius rods, one of which connects one end of the rear axle to the corresponding end of the bearing that supports the differential shaft. The test of this adjustment can be made by cutting a stick so that it will just fit between the two sprocket wheels on which one of the chains runs. The ends of the stick may rest against the bottom of the space between the pair of adjacent teeth on each sprocket wheel. Both ends of the rear axle should be adjusted so that the stick, when used in this manner, will indicate the same distance between the sprocket wheels. It

is advisable to repeat the test for different positions of the road wheels and the differential shaft in order to determine any inaccuracy in the form of the sprocket wheels. The chains should not be drawn tight, but should be left loose enough to be moved an inch or two sidewise in the center of the stretch. If one chain is worn more than the other, it will be impossible to adjust them to equal tightness and still keep the rear axle parallel with the differential shaft. However, it is better to keep the axle and shaft parallel than to throw them out of parallel in order to give the two chains equal tension.

86. Driving a Car With a Broken Side Chain.—If, while on the road, one of the side chains of a car is broken and cannot be repaired, the car can still be driven, provided the roads are good and have no very steep hills. To drive a car with only one chain, the sprocket wheel on the end of the differential shaft whose chain is gone must be locked so that it cannot rotate. This may be done by using a wooden clamp or some other suitable device. Under such conditions, when power is applied by the engine, the road wheel whose chain is still intact will be driven at twice the speed, relative to the rotation of the engine, that it would ordinarily be driven. It is therefore desirable to put the change-speed gears in one of the slower speeds. When driving in this manner, the differential gears are put into active service, and for this reason it is important that they be thoroughly lubricated. The actual strain on the differential gears is not greater than when the car is operating in the usual manner, but the tendency to wear is very much greater on account of the rapid rotation of these gears on their supports, exclusive of the gear that is fastened to the shaft carrying the sprocket wheel that is locked so as to prevent its rotation.

LOCATING SOURCE OF UNDUE FRICTION

87. Frequently, on account of undue friction in some of the bearings or other parts, excessive power may be required to drive the car. This excessive demand for power may very

easily be mistaken for failure of the engine to develop full power. On the other hand, the fault may be due to excessive frictional resistance in the engine itself. Cranking the engine will of course show at once whether it turns as freely as it should. If the engine turns freely, it can then be readily determined whether or not the transmission is offering too great resistance to the engine. In order to make this test, jack up both rear road wheels, put the transmission gears into mesh so as to drive the car on any speed that may be selected, let the friction clutch into engagement, and crank the engine as before. The power required to rotate the engine should not be appreciably greater than when the friction clutch is disengaged. It is advisable to test in this manner for each setting of the change-speed gears. If excessive frictional resistance is found to be in the transmission system, then it can be determined whether the resistance is in the part between the engine and change-gear case by setting the change-speed gears in neutral position and cranking the engine. If the engine turns harder than usual, the trouble is on the engine side of the change-speed gears. The test of the remainder of the transmission system can be made by rotating first one road wheel and then the other, to determine whether the fault is in the wheel and axle or in the driving part next to it. If both wheels rotate freely, one can be lowered so as to rest upon the road or floor and the other rotated. By this method, the remaining parts between the wheels and change-speed gears will have to move, and undue frictional resistance to their motion will be apparent.

TROUBLES AND REMEDIES
(PART 2)

CARBURETER AND IGNITION TROUBLES

CARBURETER DISTURBANCES

FAULTY MIXTURE

1. Overrich Mixture.—If a mixture is very rich, that is, if there is an excessive amount of gasoline in the charge, black smoke will appear in the exhaust. If the mixture is too rich, but not rich enough to produce smoke, it will still produce a pungent, acid odor in the exhaust, and will cause overheating of the radiator, unnecessary sooting of the plugs, accumulation of carbon in the combustion chamber, and unnecessarily rapid consumption of gasoline, with diminished power. An automobile of from 12 to 20 horsepower running at an average speed of 20 miles an hour on good and fairly level roads should be able to cover 20 miles on a consumption of 1 United States gallon of gasoline. If it does not do this, the carbureter either is incorrectly adjusted or is inefficient.

The causes of an overrich mixture are faulty carbureter adjustment; leaky float; leaky float valves; float too high on its stem or too heavy; spray nozzle loosened or unscrewed by vibration; and dirt on the wire-gauze screen over the mouth of the air-intake pipe.

Dirt over the intake may have gathered gradually or it may have been splashed on from a muddy road. Its effect is to

increase the suction in the spray chamber and to diminish the air taken in. If necessary, a shield should be fitted to prevent mud from reaching the air intake and carbureter.

2. If the level of gasoline in the float chamber of a carbureter is too high, the carbureter is said to be *flooded*. The result of a flooded carbureter is a mixture too rich in gasoline, which, owing to the absence of sufficient oxygen, is non-explosive.

In order to remedy flooding in a two-cycle engine, it may be necessary to open the drain cock in the lowest part of the crank-case and then draw off the contents, taking care, however, to replace the lubricating oil drawn off with a fresh supply. If there is no drain cock, it will be necessary to turn the flywheel many times to exhaust the excess of gasoline in the crank-case, leaving the switch closed and the compression relieved as much as possible. After a while, an explosion should take place, and this should be followed by another, the explosions gradually becoming more frequent, until finally the engine may run with an explosion at every other revolution or so. The gasoline valve should be kept closed until the charges explode regularly and the smoky exhaust disappears, after which the gasoline may be turned on and regulated at the needle valve in the carbureter. This valve should be closed slightly at first, and if the engine slows down somewhat, the valve should be opened slightly until it is possible to tell whether the carbureter is getting too little or too much gasoline.

In case of flooding in a four-cycle engine, two or three revolutions of the crank-shaft will usually dispose of any excess of gasoline, for there cannot be as large an amount in the exhaust piping of a four-cycle engine as could accumulate in the crank-case of a two-cycle engine. In a two-cycle engine, trouble from flooding is the first thing to be suspected when the engine refuses to start readily.

3. Weak Mixture.—Among the symptoms of trouble produced by a weak mixture are insufficient development of power, although the explosions may be regular, and a tend-

ency to preignite or to burn very rapidly if there is the slightest carbon deposit; also, the engine sometimes will miss every other explosion, and there is likely to be difficulty in starting the engine. It is not always easy to distinguish between lack of power due to an overrich mixture and that due to a weak mixture. However, the tendency of the former is to produce black smoke and explode in the muffler, and that of the latter is to preignite, and cause back firing into the carbureter, as well as misfiring.

Some experimenting with the carbureter adjustment will often be necessary in order to determine whether the mixture is too rich or too weak. A mixture may be richer at some speeds than at others, and if the carbureter has been readjusted, for example, in the attempt to correct trouble due in reality to a heavy float, the result will be to make the mixture faulty again at certain other speeds. Special causes of weak mixture are dirt or waste in the gasoline pipe or strainer; stale gasoline; carbureter too cold to vaporize the fuel; dirt in the spray nozzle; and float too light or too low on its stem.

Experimenting with the carbureter adjustment should be very cautiously done, with the original setting or adjustment marked so that it can be restored if necessary. The carbureter should then be adjusted slightly in one direction or the other, and the effect noted before further change is made. Very often a combination of adjustments will be necessary, but it is best to make them one at a time. If a radical change is made, it may be very difficult to start the engine at all, and this would leave the experimenter completely in the dark as to what was required.

4. A leak in an inlet pipe allows air to be drawn into the mixture so that the charge is diluted. If the leak is in a branch that leads to one cylinder only, then that cylinder will receive a weak mixture while the others may obtain one of proper proportions. If the air leak is large, the dilution of the mixture for the one cylinder will be sufficient to cause misfiring and possibly back firing into the carbureter, although the latter is properly adjusted for the remaining cylinders.

If the inlet pipe has only two branches for supplying four cylinders, which is a construction very commonly found, then a leak in one of these branches will cause a weak mixture to be delivered to two of the cylinders, while the other two may be receiving a perfect mixture from a properly adjusted carbureter. The result will be misfiring and possibly back firing in two of the cylinders, while the other two that receive the perfect mixture will operate satisfactorily.

It is generally not difficult to discover a large leak in an inlet pipe. By holding the hand around the pipe where a leak is suspected, but not so closely as to close the leak, the current of ingoing air can generally be felt. However, if the leak is small, as it may be around a joint in a pipe, so that the current of air cannot be felt by the hand, a liberal supply of cylinder oil placed around the joint will generally indicate a leak, because the oil will be drawn into the mixture pipe. The remedy for a leak in an inlet pipe is to repack or otherwise refit the leaky joint.

EFFECTS OF DIRT IN GASOLINE SYSTEM

5. Dirt in Carbureter.—If there is dirt on the float valve, it will prevent this valve from closing and will cause the carbureter to flood. Flooding will produce an overrich mixture, especially at low speeds, and is highly dangerous on account of the liability to fire. If the dirt is in the spray nozzle, it will produce a weak mixture. If the dirt has been splashed into the air intake, it will produce an overrich mixture, especially at high speeds.

The remedies for trouble due to dirt in the carbureter will become obvious when the nature of the trouble is located. A carbureter that has previously worked well and that suddenly begins to leak has in all probability dirt in the float valve. A carbureter that suddenly gives a very weak mixture and makes the engine hard to start probably has dirt in the gasoline pipe, the strainer, or the spray nozzle. A liberal priming of the carbureter may wash the particles of dirt out of the spray nozzle or the float-valve seat.

If the engine has been running well, but without apparent cause fails to produce enough power to propel the car up a hill, or if it stops but can be readily started, but still fails to propel the car up the hill, there is evidently some hindrance to a free and normal flow of gasoline. The hindrance may be in the form of an obstruction at the spray nozzle, at the float valve, or in the gasoline pipe. Such an obstruction may often be dislodged by disconnecting the gasoline pipe and blowing air through the carbureter with a tire pump.

6. Dirt or Waste in Gasoline Pipe.—It is a common practice to carry a bunch of waste under the seat of an automobile. Usually, the gasoline tank is located near the seat, and in time a sufficient quantity of fluff from the waste may enter through the vent hole in the feed-cap of the tank to create an appreciable obstruction in the gasoline pipe. Even if this does not happen, dirt or other obstructions will sometimes accumulate, especially if the gasoline is not always properly strained. The symptom is a sudden or gradual weakness of the mixture, necessitating readjustment of the carbureter in order to keep the engine running. The most probable place of lodgment for obstructions of this sort is in the gasoline pipe at the point where the latter connects to the carbureter, or at the strainer, through which the gasoline generally passes just before it enters the float chamber. Disconnecting the gasoline pipe or the union and thus exposing this strainer will generally disclose the obstruction. Sometimes it may be necessary to disconnect the gasoline pipe at both ends and then blow it out with the tire pump. This operation is necessary only when the pipe has been disconnected near the carbureter and gasoline does not flow freely from it when turned on at the tank.

FLOAT TROUBLES

7. Leaky Float Valve.—With a leaky float valve, the carbureter drips when the main gasoline valve is opened. The leakage is not stopped by a priming that would remove

a small particle of dirt on the float-valve seat or in the spray nozzle that might cause a temporary flooding. The trouble may be remedied, however, by grinding the valve to its seat with very fine emery or some similar abrasive.

8. **Leaky Float.**—If a metallic float has become leaky, and hence partly or entirely filled with gasoline, and its buoyancy has thus been destroyed, the float valve will be held away from its seat and the carbureter will be flooded continually, as in the case of a leaky float valve. If the float is thought to be partly filled, shaking it will reveal this condition by the swishing noise produced. A float that is full or almost full is indicated at once by its increased weight.

The location of the leak can often be determined by a careful inspection of the entire surface of the float. In some cases, however, the leak is very minute, and it may become necessary to immerse the float in quite hot water in order to vaporize the gasoline that it contains; bubbles due to the escape of gasoline vapor will then disclose the location of the leak.

Before attempting to repair the leak by soldering, great care must be taken to remove any gasoline or water that the float may contain, heating it so as to evaporate the gasoline, if necessary. In case the float contains water, a small hole through which the water can trickle out may have to be punched into the float. In soldering the leak, as little solder as possible should be used, in order not to change the buoyancy of the float to an appreciable extent.

9. A cork float that has become saturated with gasoline, or *loggy*, as it is usually called, should first of all be thoroughly dried. It may then be rendered impervious to gasoline by varnishing it with shellac varnish, which is not soluble in gasoline, and letting the shellac dry for 24 hours. Ordinary furniture or coach varnish must not be used, because gasoline will dissolve it.

10. **Float Too High.**—By the expression *float too high* is meant that the float is set too high on its stem, or that the valve lever is too high when actuated by the bottom of

the float or too low when actuated by the top of the float. When the float is too high, it is not lifted by the gasoline sufficiently to close the float valve before gasoline escapes from the spray nozzle.

If this trouble is present, the carbureter drips when the main gasoline valve is opened. If the spray orifice can be covered by the finger, the float valve will be closed by the float. The float valve also closes tight if it can be manipulated by the fingers, or if the float can be lifted by a pair of bent wires. When trouble is experienced from a float that is too high, a metallic float will be found empty and a cork float not gasoline-soaked.

Trouble of this kind may be remedied by bending the levers by which the float acts on the float valve. If this cannot be done, the float should be shifted $\frac{1}{16}$ inch lower on the stem by the use of a soldering iron.

11. Float Too Heavy.—The same symptoms are present when the float is too heavy as when the float is too high, but they are caused generally by a leak in the float or by a float that is gasoline-soaked. In a hollow metal float, there will sometimes be found a minute leak that is generally due to defective soldering or to the metal itself having cracked. The float of a carbureter sometimes sticks so that it does not rise as the gasoline flows in from the supply tank. This trouble, of course, will cause an overrich mixture. The float can usually be shaken loose by striking the carbureter a sharp tap with a stick or a light piece of metal. If it cannot be loosened in this manner, the obvious remedy is to open the carbureter and lift the float. The fault should be removed at once.

12. Float Too Light or Float Adjusted Too Low. The expressions *float too light* and *float adjusted too low* mean that the float is lifted by the gasoline in the float chamber when the gasoline level is still some distance below the orifice of the spray nozzle.

Among the symptoms of trouble produced by a light float or a low adjustment are a weak mixture at slow speed and

probably difficulty in starting the engine, owing to the fact that considerable suction is required to lift the gasoline to the mouth of the spray nozzle.

To remedy the trouble, the float must be weighted slightly, the valve lever must be bent up if it is worked by the bottom of the float or bent down if worked by the top of the float, or the float must be adjusted in some other way so that the gasoline will rise higher before the float closes its valve. The weight may take the form of a few drops of solder carefully distributed over the float so as not to overbalance it; or, if this is not sufficient, a ring of sheet brass may be soldered to the top of the float. Altering the weight of the float, however, is very seldom necessary.

FROZEN CARBURETER

13. A frozen carbureter may occur in winter, provided there is no provision for heating either the carbureter or the air that passes through it. Freezing is most likely to occur in very damp, cold weather; however, it is not a very common occurrence.

When running over wet roads, especially those covered with slush, water may be thrown into the air-inlet pipe if the latter is not sufficiently protected. This water may be first thrown on some of the rotating parts of the engine, and it may then fly off so as to reach the air intake. If the carbureter is of a form that allows this water to collect in some part of it, a large, solid lump of ice may be formed. The air passage may be so obstructed by this ice as to prevent operation of the carbureter.

In many designs of carbureters, one of the first effects of ice or frost is to lock the throttle valve so that the power developed by the engine cannot be controlled by the throttle.

The method to be employed in removing the ice from the carbureter depends chiefly on its form and location. If the carbureter is near some of the warm parts of the engine and the latter is in a sheltered place, the heat of the engine will generally thaw the ice, provided the car is left standing idle

for a short time. If an engine with more than one cylinder does not thaw in this manner, it is sometimes possible to run the engine while holding the inlet valve of one cylinder open so that the compression stroke will force the warm gas from the corresponding cylinder back past the open inlet valve and through the carbureter. In this manner, the carbureter may be sufficiently warmed to melt the ice. Warm or hot water from the radiator or elsewhere may be poured over the outside of the carbureter to thaw the ice, but care must be taken not to get any water into the carbureter. Should any water accidentally reach the inside, however, it must be carefully removed. Under no consideration should a gasoline torch or an alcohol lamp be used to heat the carbureter, as it may set fire to the gasoline.

FUEL TROUBLES AND BACK FIRING

14. Water in Gasoline.—Water may be found in gasoline taken from a barrel standing out of doors. The water, being heavier than the gasoline, will always settle to the bottom, and by close observation it may be seen before it is poured into the tank. If the gasoline is strained through a piece of chamois skin, through several layers of cheese cloth, or even through very fine brass-wire gauze, the strainer will hold the water while permitting the gasoline to pass through. The user should make it an invariable rule to strain all gasoline in this manner.

The symptom of water in the gasoline will be immediate stoppage of the engine when the water reaches the spray nozzle, in spite of the facts that the timer, coils, battery, spark plugs, etc. are in perfect order and that the gasoline tank is known not to be empty. The only remedy is to unscrew the wash-out plug at the bottom of the carbureter or gasoline tank, and then let the water and gasoline run out until it is certain that all the water has escaped. Sometimes, in order to expel the last drop of water, the gasoline pipe may have to be entirely disconnected and then blown out.

15. Stale Gasoline.—If an automobile has been left standing unused for some time, say 6 months or more, some of the gasoline in the tank may evaporate; also, it may get too stale to give a correct mixture without readjustment of the carbureter. The usual symptoms of stale gasoline are difficulty in starting the engine and insufficient power, owing to a weak mixture. The best remedy in such cases is simply to fill up the tank, when the mixture of old and fresh liquid will probably work satisfactorily. It may be necessary, however, to readjust the carbureter or to throw away the stale fuel.

It frequently happens when touring that the gasoline procured at country stores is very stale. For this reason it is always well to test the gasoline with a hydrometer. The user should know the density for which the carbureter is adjusted, and should not depart from this more than is necessary. Ordinary stove gasoline formerly tested 74° to 76°, Baumé scale, but that now in the market tests from 66° to 70°, Baumé scale.

16. Back Firing Into Carbureter.—The cause of back firing through the inlet valve is generally a delayed combustion of a weak mixture containing an insufficient amount of fuel. The result of such a mixture is a weak explosion and slow burning, so that, during the entire exhaust stroke and even at the beginning of the suction stroke, there is a flame in the combustion chamber. The fresh charge will therefore be ignited by the flame of the delayed combustion of the previous charge; and, as the inlet valve at that time is open toward the air-supply pipe or passage, an explosion will occur in either the intake pipes or the carbureter. The remedy for this condition is to increase the fuel supply or to decrease the air supply until the explosions become of normal strength and back firing ceases.

Explosions in the carbureter may also be caused by an inlet valve failing to close, thus permitting the mixture burning in the cylinder to ignite that in the inlet pipes and the carbureter.

A back firing into the inlet pipe and carbureter may also occur when, through defective valve timing, the inlet valve opens some time before the exhaust valve closes.

DEFECTS OF IGNITION SYSTEMS

BATTERY TROUBLES

17. Missed explosions may result from a weak battery. To test for a spark, disconnect the wire from the spark plug and hold it with a dry cloth or a wooden-handled screwdriver so that the bare end will be $\frac{3}{32}$ to $\frac{1}{8}$ inch from any metal part of the engine. If a spark is produced when the switch is closed and the timer closes the circuit for one of the cylinders, the battery is probably strong enough and the vibrator is working properly; in fact, under such circumstances, the only electrical troubles that would cause misfiring would be loose connections or imperfect closure of the circuit by the timer while the engine is running. If the battery is weak, the spark will be weak and will not jump across the air gap.

It is sometimes difficult to determine whether the explosions are missed because the battery is weak or because of a loose connection or broken wire somewhere in the ignition circuits. The only reliable way to determine this point, unless there is a fresh set of cells in reserve, is to test the cells by means of a battery tester as soon as skipping occurs. The battery strength required will depend on the character of the coil, but it is not often that a dry cell showing less than 5 amperes on short circuit is worth retaining.

If both sets of dry batteries are so exhausted that neither will work the coil, the two may be coupled in parallel or, less preferably, in series. Under these conditions, it will generally be possible to run the car for some miles farther. When home is reached the batteries should be replaced.

18. Dry cells that have become exhausted can often be made to give current for a short time by pouring through

holes punched into the sealing paste at the top as much water, cider vinegar, or muriatic acid as the cell will absorb. The best results will be obtained from the use of muriatic acid, in the handling of which great care must be taken; cider vinegar is next in efficiency, and water is the least efficient.

19. By means of a small electrical buzzer or bell, each cell may be tested separately, and by the tone or sound produced, it can usually be observed whether or not the battery needs renewing. A small pocket ammeter and a voltmeter are very convenient for the purpose of testing batteries.

It is customary to install six, or even eight, dry cells connected in series into one battery. It is never safe, however, to depend on a single battery. A reserve set of dry cells—the same in number as the set ordinarily used—carefully wired up should always be carried if a storage battery or magneto is not employed as the source of current.

SPARK-PLUG TROUBLES

20. Current Leakage.—Sufficient leakage of current from a spark plug to make trouble—but not enough to be observed without testing—may be due to moisture in the mica insulation of the insulated electrode or to a bridge of carbon. When it is suspected that the trouble is due to either of these causes, a good plan is to dry out the insulation thoroughly and to clean the lower end with a brush or a piece of waste and a little gasoline. These troubles are more liable to occur when the batteries have become weak from use or are so far exhausted that they will not give sufficient current for ignition.

21. Broken Spark-Plug Insulation.—Spark plugs often fail to operate properly on account of imperfect insulation. Porcelain insulation ordinarily becomes defective only by cracking completely through. Mica insulation, if made up of a large number of thin washers or disks in the usual manner, becomes defective by shrinkage of the disks. Carbon and oil then collect between the disks and form a short

circuit for the high-tension current. Mica insulation sometimes, but very infrequently, fails by crumbling, when it looks very much like the worm-eaten portion of a piece of wood. The insulation is, of course, entirely useless after reaching this condition.

Steatite (soapstone) insulation is not so apt to crack as porcelain. However, practically the only way in which this insulation fails is by cracking.

22. The breaking of a spark-plug porcelain usually results in complete failure to ignite the charge in that particular cylinder, owing to the secondary current being short-circuited through the break. The outer end of the porcelain will generally be loose when tried by the fingers. The only remedy is a new porcelain or a new plug. Breaking is usually caused by screwing the bushing down too tight. If the asbestos packing is of uneven thickness, screwing down the bushing tight enough to prevent leakage may crack the porcelain. Overheating and splashing of water on a hot porcelain will also cause breaking.

The remedies for such trouble are found in using new asbestos packing and in providing protection from water, etc. The only remedy for defective mica insulation is to take it apart and thoroughly clean it, and even this remedy is a doubtful one and is likely to be expensive. It is generally cheaper to use a new plug, or, at least, a new insulating core piece.

23. Soot on Spark-Plug Porcelain.—Soot on the spark-plug porcelain will cause misfiring, or total failure to ignite, when the battery is of proper strength and the vibrators on the coils are working properly. If the engine has more than one cylinder, probably one or more will be found to be working properly, in which case the one with the defective spark plug may be located by holding down one coil vibrator after another, thus stopping explosions in each cylinder in turn, until the vibrator feeding the inactive cylinder is reached. By listening carefully to the exhaust when one cylinder is known to be misfiring, it will be observed that

depressing the vibrator of an active cylinder will cause a noticeable break in the cycle of explosions. When the vibrator of an inactive cylinder is depressed, no such break will be noticed. It is, of course, necessary to know which cylinder is fed by each vibrator. A spark plug may spark properly in the open air, but not at all in the cylinder, as the electrical resistance of air increases greatly when the air is compressed. If a plug is slightly sooted, and there is uncertainty as to whether the trouble is due to the soot or to something else, a fresh plug should be inserted and the result noted. If there are no spare plugs at hand, one may be substituted from another cylinder. A make-and-break sparker coated with soot will act nearly the same as a sooted plug. The extra current producing the spark will leak away to a considerable extent through the carbon instead of producing an effective spark.

The causes of sooting are too much lubricating oil, inferior oil, or a too rich mixture. The overrich mixture will deposit pure black soot, whereas an excessive quantity of lubricating oil will produce a rusty-brown deposit. Inferior oil may produce almost any sort of deposit, according to its quality. A great excess of either good or bad oil will not burn completely before it reaches the plug, and will deposit on the latter a greasy mixture of carbon and oil. An engine receiving oil in such quantities as this will foul the plugs within a mile or two, and energetic measures must therefore be taken to get rid of the surplus oil.

When the faulty operation of a plug is due only to carbon deposit on it, the plug can be cleaned, provided the insulation is accessible, by a piece of cloth moistened with gasoline. A stiff brush may be found convenient if the plug has sharp angles and corners. Some plugs are of such form that it is impossible to reach the insulation for cleaning purposes without taking the plug apart.

24. Leaky Spark Plug.—If there is a leak between the plug shell and the cylinder, it will be denoted by the hiss of escaping gas on the compression and power strokes. In such

cases, the plug may be screwed tighter or a new gasket used. If the leak is through or past the packing inside the plug, the same hiss will be heard, and, in addition, the outer end of the porcelain will show traces of soot after the gases have been leaking for some time. If the plug bushing has already been screwed as tight as is prudent, with regard to the safety of the porcelain, it will be necessary to repack the plug. A plug allowed to leak to any noticeable extent will overheat, cracking the porcelain or burning the screw threads.

25. Space Between Spark Points.—A spark plug that sparks perfectly when removed from the cylinder and is otherwise good may fail to ignite the charge when in place because the spark points are located too far apart. Generally speaking, the distance between the spark points should not be less than $\frac{1}{64}$ inch nor more than $\frac{1}{32}$ inch. If upon examination the spark points are found to be too far apart, they can be brought closer together, at least in many designs of spark plugs, by bending one or both with a pair of pliers.

MAKE-AND-BREAK IGNITER TROUBLES

26. Poor Contacts.—In order to obtain a spark of sufficient size in the combustion chambers of engines equipped with the make-and-break system of ignition, it is necessary that a good contact be made between the two electrodes of the igniter plug before they separate. The current passes through the bearing of the movable electrode, and if the contact between the bearing and the stem of the electrode is poor, only a weak current can find its way to the point of contact, resulting in a feeble spark that may be too weak to fire the compressed mixture. Poor contact of the electrode may be caused by an inferior quality of lubricating oil forming a thin layer of carbon (which is a poor conductor) on the stem, or it may be due to wear of the bearing and a loose-fitting stem. To prevent wear on the stem and bearing, it is important that the seat of the electrode be kept tight, so as to prevent the heat of the burning charge from reaching the

stem and to keep the stem as cool as possible. This will aid in keeping the stem well lubricated, as the oil cannot be burned and form the objectionable carbon deposit. At the same time, the electrode will move easily without sticking, which is essential to a prompt separation of the two contact points.

Low-tension electrodes sometimes give trouble either on account of fusing and pitting of the contact points or on account of defective insulation. When the contact points become burned and pitted, they make either imperfect electric connection or none at all, so that at least part of the time no spark is formed at the instant of their separation.

The contact points can usually be repaired by filing them with a smooth-cut file or grinding them with a piece of whetstone. The spark points should be examined to see that they are tight in the part that carries them.

The contact igniter sometimes becomes inoperative on account of wearing in such a manner that the contact points are not separated by the action of the mechanism that is intended to operate them.

27. Short Circuits.—A ground, or short circuit, is often responsible for difficulties or failures of the igniter. The short circuit may be caused by carbonized oil on the exposed surface of the insulators or by dampness between the mica washers, provided these are used for insulation. By placing the igniter plug in a warm place and drying it thoroughly, a short circuit of this kind can often be remedied.

28. Short-Time Contact.—The length of time during which the electrode points are in contact has a decided effect on the size of the spark. To test whether the contact is of sufficient duration, hold the two points together by exerting pressure by hand on the movable electrode. If this is found to cure the trouble, it is a sure indication that the contact is too short, in which case the parts that make the contact must be adjusted so as to prolong the time of contact. This adjustment is made in some igniters by increasing the tension of the igniter contact spring, and in

others by changing the relative positions of the interrupter lever of the movable electrode and the blade of the igniter lever that operates it and presses it against the fixed electrode.

COIL DERANGEMENTS

29. Vibrator Out of Adjustment.—If the vibrator sticks, the symptom will be erratic firing. Few or no explosions will be missed, but the impulses will sometimes be very weak because the sticking causes a very late spark. Too light a pressure of the contact screw will cause the engine to run weak and fitfully; too much pressure will exhaust the battery rapidly. Each condition will manifest itself to the practiced ear by the sound of the vibrator. Poor firing may be caused also by pitting of the contact points. This trouble may be remedied by filing the contact points, which should bear squarely against each other, and readjusting the spring and contact screw.

30. Defective Condenser.—A condenser that is short-circuited or has one of the connections broken will show it by excessive sparking at the trembler and timer contacts, and by rapid burning of the metal where the spark occurs. The only remedy is to send the coil to the factory for repairs.

31. Short-Circuited Coil.—A spark coil may short-circuit from breakdown of the insulation in either the primary or the secondary winding. The symptoms of this trouble are a poor spark or none at all, and refusal of the vibrator to work, even with a good battery. The only remedy is to send the coil to the factory for repairs. The spark coil must be kept in a thoroughly dry place, as moisture will surely cause trouble and will interfere with the passage of current through the coil to the engine. If the spark coil is found to be moist, it can generally be put into serviceable condition by drying it in an oven that is not too hot.

WIRING TROUBLES

32. Break in Primary Circuit.—The symptoms produced by a break in the primary circuit, which includes all wiring except from the coil to the plug, or from a secondary distributor to the plugs, are intermittent sparking or complete failure to spark, according to whether the connection is intermittently restored by vibration or is wholly broken, and failure of the vibrators to work.

The almost invariable cause of breaks in the primary circuit is vibration, which will loosen nuts on binding posts and sometimes break wires in unexpected places.

The first step to be taken in remedying the trouble is to test every binding post, usually by shaking the wires with the fingers. If this does not disclose the trouble, hunt for a break in the wiring. It will generally be found close to a binding post, switch terminal, or other connection, where the bending due to vibration is most severe. As a last resort, close the switch, open the compression relief cocks, retard the spark, and turn the crank so as to make contact at the timer. Then, with a length of spare wire, shunt successively each wire in the primary circuit by touching the ends of the spare wire to the ends of the regular wire until the one with the break is found. The spare wire thus bridges the break in the regular wire and causes the igniter to operate. Then hunt down the break in that particular wire, or take it out and put in a new one. If the wire has a soldered joint, it may be brittle at that joint and may have broken; or, it may have been fastened in such a manner as to strain it; or a badly made and twisted joint may have worked loose. Note that the break may be between the timer and the coil, in which case it will affect only one coil.

A wire is quite likely to break inside its insulation, or just at the point where the insulation has been stripped off. A troublesome kind of break is that which is opened only by the vibration of running and is closed by the elasticity of the wire or insulation, or by the weight of the battery cells or other connected members, when the car is stopped. A great

deal of patience is sometimes needed to trace a break of this kind.

33. Short Circuit, or Ground, in Primary.—A short circuit, or ground, in the primary conductor is not a common trouble, and it can usually be avoided if ordinary care is taken in insulating the primary. The symptoms of such trouble are much like those due to a broken wire, but an ammeter test close to the battery will show that current is flowing. The short circuit is most likely to be caused by the chafing through of the insulation of poorly supported wires, or by neglect to insulate properly some home-made attachment in the circuit. It may be due to contact of the dry primary cells with bolts passing through the battery box.

34. Broken Secondary Cable.—As the secondary cables are short and thick, a break in them is an unusual occurrence. If the break is not too great, the current will jump it, and the sparking there will at once disclose the trouble.

35. Grounded Secondary Cable.—A grounded secondary cable, which is indicated by failure to spark when the vibrator is working, is generally due to the chafing through of insulation on a badly supported cable. Sometimes it is due to rotting of rubber insulation by heat and oil. If the secondary cable has been spliced and taped, the current will go through the tape unless the cable is well out of the way of grounded metal work near the splice. Such a cable may give a spark at the plug as well as at the ground, and this will soon exhaust the battery, because the vibrator would require to be adjusted for a greater current consumption in order to compensate for the leakage of current and at the same time produce an effective spark.

The roadside remedy for a grounded secondary wire is to tie the cable clear of the metal work. The permanent remedy is to put in a fresh cable that is adequately protected by fiber tubes or other insulating supports. A cable with a varnished exterior is the best, as it resists oil. A rubber-covered cable exposed to oil may be protected by a coat of shellac or a layer or two of tape.

36. Loose Electrical Connections.—To obviate failure to start because of loose or defective electrical connections, the ignition mechanism should be tested carefully. With the make-and-break system of ignition this test is made by disconnecting the wire from the binding post or nut of the insulated electrode while the electrodes are in contact, and then snapping the end of the wire across the binding nut of the insulated electrode. If a good fat spark is produced when the wire slips off the nut, thus breaking the circuit, it is evident that the circuit is not defective beyond the igniter and that the contact between the electrodes is good.

If, with the wire connected to the insulated electrode and with the igniter contact points separated, a screwdriver is placed so as to make contact with the binding nut of the insulated electrode and with a capscrew, stud bolt, or some bright part of the engine, the production of a spark when the contact between the screwdriver and the nut of the insulated electrode is broken will indicate that no short circuit exists in the igniter. If, however, no spark is produced on breaking contact with the screwdriver, it will indicate the existence of a short circuit or an open circuit that should be found and eliminated. If a spark is produced on breaking contact with the screwdriver when the two electrodes are in contact, it will be evidence of poor contact between the points. No spark will appear on breaking the circuit when the contact between the points is good.

The breaking of a wire inside the insulation, while not of frequent occurrence, is harder to locate than a loose electrical connection. In cases where it appears to be impossible to find the trouble, the existence of the broken wire may be determined by running a temporary wire from the spark coil to the engine, and the spark coil to the switch or battery, as the broken wire may sometimes open and sometimes close the circuit.

A loose rocker-arm fastened to the movable electrode of a make-and-break igniter will sometimes give considerable trouble that will be found difficult to locate. A very little lost motion, where the shaft is small, is increased rapidly;

and, as soon as the shaft becomes the least bit loose, the pounding to which it is subjected will cause it to loosen very quickly.

Switches should have good, clean contact points, as otherwise they may cause trouble in any ignition system.

TIMER TROUBLES

37. Timer Contacts Roughened by Sparking. Trouble due to roughening of the timer contacts by sparking is likely to occur in any timer in which the contact segments are inserted flush with the insulator barrel or internal ring, instead of projecting therefrom.

The symptom produced by roughened contacts is irregular firing, due to the jumping of the contact roller or fingers. This fault is not noticeable at low speeds, but becomes marked as the speed increases. The remedy is to true the insulator ring and segments in a lathe, and, if necessary, put in a new roller or contact fingers.

Loose connections at the timer binding posts will cause either misfiring or irregular firing.

38. Wabbling Timer.—Some timers have their stationary portion supported on the shaft by a very short bearing that quickly wears loose and allows the stationary portion to wabble out of its correct plane. This will cause irregular firing or even misfiring. One may easily determine whether the cause of the misfiring is here or elsewhere by steadying the timer with the hand. The remedy is to bush the bearing, and, if possible, to make it longer.

39. Loose Timer Rotor.—In the modern form of timers, a loose rotor, on account of the secure method of fastening employed, is rare; but in some of the earlier forms and also in the cheaper ones still in use, the rotor is fastened to the shaft that drives it by means of a setscrew that is very apt to work loose during the operation of the timer. If this setscrew becomes so loose as to work round on its shaft gradually and in the direction opposite the rotation of the

shaft, it is liable to produce some extremely erratic results in the operation of the engine. If it gradually works back, the spark lever will have to be advanced gradually in order to compensate for the backward creeping of the rotor. After the rotor has worked back so far that the engine will not run well, it may be possible that retarding the spark completely will bring the ignition at about the proper advance for the operation of the engine. The process of the creeping back of the rotor and the advance of the spark lever may then be repeated as before. More often, however, the rotor moves by jumps and starts on its shaft, and the engine consequently operates in a manner difficult to describe in any other way than to say that it is erratic.

A temporary remedy is to tighten the setscrew into the countersink with which the shaft should be provided. The permanent remedy is either to get a new timer or to fasten the rotor rigidly to its shaft by either a pin or a key. Unfortunately, some of the rotors that have the fault just mentioned are of hardened material, so that they cannot be drilled or slotted for the keyway without drawing the temper of the material. In some timers, the rotor has a ring of insulating material, generally vulcanized wood fiber. This ring carries a brass contact piece that is fastened to the ring by means of a single radial screw that passes through the contact piece and is threaded into the wood fiber. The length of the screw is such that its point extends a slight distance into the hole through the ring. This projection of the screw is to hold the rotor in place on its shaft. The design is an unfortunate one. If the screw works loose, as it is very apt to do, it will generally allow the insulated ring to move about so that the point of the screw will sometimes touch the shaft and sometimes not touch it. When a screw does not touch the shaft, there is of course no electric circuit from the contact piece of the shaft, and, consequently, the timer cannot close the circuit. The engine therefore behaves most erratically, sometimes running well for awhile and then misfiring in a most unexplainable manner. This form of timer may also behave part of the time in the same manner as previously described.

40. Worn Timer Contacts.—A timer whose stationary contacts wear so that they become somewhat loose, as in the case of rollers supported on stationary pins, will not always close the primary circuit at the same instant relative to the motion of the piston. The worn rollers shake about on their pins so that at one time they will make earlier contact with the rotor than at another. This condition is not generally remedied by putting grease into the timer so as to prevent the rollers from shaking about loosely; they will take different positions despite the grease.

41. Incorrect Timing.—With engines having make-and-break ignition mechanism, even if the current is sufficient and there are no leaks, the time of contact may be too short, may be made at the wrong point in the stroke, or may be broken when it should not be, owing to incorrect timing. The timing may be tested by turning the flywheel carefully in the proper direction, and noting when the contact is made and at what point the spark occurs. By scratching the flywheel at these points when the engine is running satisfactorily, it is always a simple matter to correct any trouble in the time of sparking. Raising or lowering the igniter pin without following any particular rule or without knowledge of what one is doing is very bad practice, and is more likely to aggravate than to remedy the difficulty. In multicylinder engines, it evidently is quite important that there should be for each cylinder the same relative time of making and breaking the contact, with the same length of time in contact.

TESTING THE IGNITION SYSTEM

TESTING JUMP-SPARK BATTERY SYSTEMS

42. General Directions.—The order in which the various steps of a test of an ignition system can be made to the best advantage naturally depends to a great extent on the form and accessibility of the different parts of the system.

Thus, if a timer is in an easily accessible position, it may be examined during the early part of the search for faults; but if it is difficult of access, or if it is of a form that does not readily admit of examination, the test can possibly be made more rapidly by leaving the examination of the timer until last.

The steps here given are in the order that is most convenient for the majority of ignition systems. As soon as the fault is located, the test is naturally discontinued. In each test, the primary circuit is to be closed by the switch and also by the timer as the engine is cranked, unless another way of closing the primary circuit is mentioned. When new spark plugs for a high-tension system are at hand, and can be conveniently put in place, it is advisable to put in these new plugs before making any tests other than those which can be made quickly and easily. It should always be borne in mind that misfiring may also be due to the mixture in the cylinders not having proper proportions.

The test of a battery-ignition system can generally be made more readily when a voltmeter and an ammeter are used for measuring the pressure and current. In the following tests, however, these instruments are left out of consideration, but it is desirable to use them if they are at hand. It should always be borne in mind that a dry battery that has been standing idle for some time may operate the ignition system satisfactorily for awhile and then become so weak as to be useless.

43. Testing the Primary Circuit of a Single-Cylinder Engine.—In a single-cylinder engine with one spark plug, the tests that follow can be made in case of apparent fault in the ignition system. There should be reasonable certainty that the battery is at least in fair condition, and it will be well to assume that the connections of the primary circuit are made as illustrated in Fig. 1, in which the primary winding of the coil is shown at a; the fixed end of the vibrating spring, at i; the stationary contact point, at c; the stationary insulated contact on the timer, or commutator,

at *m*; and the rotating member of the timer that is grounded by the wire *e f* to the frame, or through the rotating shaft to the frame, at *e*. In this case, the wire *g h* runs from the frame at *g* to the battery *h k*, which consists of six cells. The switch is shown at *s* and the condenser at *l*.

The tests may be made as follows:

1. Close the hand switch that, when open, breaks the primary circuit, or put in the circuit-closing plug if one is used instead of a switch. Set the spark control lever in the retarded position.

2. Open the compression relief cock and crank the engine slowly. The trembler of the spark coil should vibrate vigorously while the primary circuit is closed by the timer; that is, when *m* and *e*, Fig. 1, are connected together by the rotating member. Press down the vibrator spring gently to separate the contact points in case they have adhered together. Examine the vibrator for a loose contact piece. Clean the contact points. If the vibrator works well, next make the test of the secondary, or high-tension, circuit described in Art. **44**, but if the vibrator does not work well, make the following test:

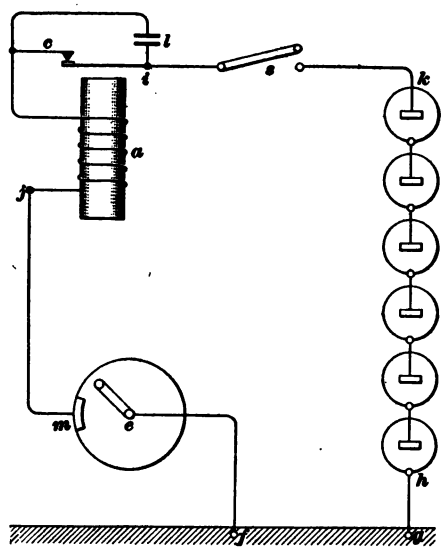


FIG. 1

3. Short-circuit the timer by connecting a wire with clean, bright ends from *j*, Fig. 1, to the frame *f*. If the vibrator works, the timer is evidently at fault, provided there was no action of the vibrator in test 2. The timer can often be short-circuited with the blade of a screwdriver held so as to

make contact with the insulated stationary contact piece *m* and also with the grounded part *e* of the timer.

4. To test for a bad primary connection, connect a wire to any part of the frame of the car or to the engine and then touch the free end of the wire against the battery terminal *h*, to which the wire coming from the frame should be connected, making sure that the circuit is closed in the timer from *m* to *e* by rotating the flywheel to the proper position. If the vibrator trembles, the fault is in the wire that connects the frame and the battery; or, it is due to a loose or dirty connection between the bare end of the wire and the frame of the car or between the other bared end of this wire and the battery terminal, to which it should be properly connected. In the same manner, test the connections from *m* to *j* and from *i* to *k*. A wire sometimes chafes so as to wear off the insulation. Defective insulation may cause the trouble, but this is not likely to be the case with the primary wire *g h* or *e f*. A break in the wire *g h* or poor connections at its ends will prevent the operation of the coil; but poor insulation will not, unless it is so poor as to amount to metallic contact with the wire *i k* or its terminals.

A wire may swing when the car is running, so as to make intermittent contact with the frame of the car, thus causing irregular action of the ignition system. It sometimes happens that a wire breaks inside its insulation without the insulation showing any evidence of it. A break of this kind is difficult to detect, but it seldom occurs. A solid wire is more subject to such breaks than is stranded wire or cable. The broken ends of the wire may sometimes touch each other, and may sometimes be separated so as to open the circuit. The best remedy is a new wire; if long enough, the wire may be cut at the faulty point and the two ends cleaned, joined securely together, and covered with electricians' tape.

5. If the vibrator did not operate in the preceding tests, put in a new battery, provided the one in use is old or there is the slightest doubt as to its being in good order. Examine the connections between the cells, between the battery and the spark coil, and between the battery and the frame of the

car. See that the binding screws of the battery do not touch each other or the metal of an adjacent cell; also make sure that the metal cups of the dry cells are not in contact with each other and that the insulation between the cells is dry. With the new battery, repeat the preceding tests as far as may be necessary. If the vibrator does not operate when the circuit is closed in the timer, the fault is probably inside the coil box.

44. Testing the Secondary Circuit of a Single-Cylinder Engine.—If the battery, timer, and the remainder of the primary-circuit connections in a single-cylinder engine are good, then the high-tension, or secondary, circuit may be tested as follows:

1. Disconnect the high-tension wire from the spark plug, fix or hold the terminal of this wire (having it thoroughly insulated from all metal parts) about ¼ inch from the metal of the engine or the metal of the spark plug, and close the primary circuit. The insulated wire can usually be held in the hand without receiving an electric shock. Sparks should pass freely across the ¼-inch gap. If there are no sparks, or if there are sparks only when the terminal of the wire is brought very close to the metal of the engine or spark plug, look for an open connection between the high-tension wire and the spark coil, defective or worn-off insulation on the wire, or a broken wire inside the insulation. Poor or defective insulating material covering more or less of the wire may be the cause of trouble. A slight break or opening has little effect on the high-tension current.

2. Remove the spark plug and connect the high-tension wire to it. Put the outer casing of the spark plug in contact with the metal of the engine. Do not hold the plug, because if the hand is in contact with the plug when the test is made a shock will almost certainly be received. The insulated wire leading to the plug can, however, usually be held to keep the plug in place without the danger of a shock. Close the primary circuit and note whether or not a spark passes between the spark points of the plug. If no spark passes, the plug is either defective or needs cleaning.

3. If a spark passes in the preceding test, the plug may still not give a spark under compression when inserted in the cylinder. If the construction of the spark plug is such that the spark points can be separated without injuring the plug, separate the points as much as $\frac{1}{4}$ inch if possible. Test again as before. If no spark passes, the plug will probably not spark when in regular service in the engine. Put the spark points of the plug into correct position, about $\frac{1}{32}$ inch apart, before replacing the plug in the engine.

The obvious remedy in the case of a defective spark plug is to put in a new plug until there is opportunity to clean the old one or to put new insulation in it.

45. Testing the Ignition Circuit of a Two-Cylinder Engine.—For a two-cylinder engine with only one spark coil and the two spark plugs in series with each other, so that a spark is formed at each plug twice as often as required, the test differs from that given in Arts. **43** and **44** only in the testing of the additional spark plug. The primary circuit would be tested in exactly the same way. One spark plug may be short-circuited while testing the other; however, both spark plugs may spark all right when tested alone, but not when they are connected in series. In the latter case, either the electrical pressure produced by the coil is not strong enough to cause a spark across both plug gaps simultaneously, or the circuit is improperly grounded or open somewhere when both plugs are connected in the circuit.

46. Testing the Ignition Circuit of a Four-Cylinder Engine With Individual Spark Coils. — There are two cases of faulty ignition that may occur in a four-cylinder, or, in fact, in any multicylinder, engine. In one case, the ignition is faulty in all the cylinders; in the other case, the ignition may be defective in either one, two, or three of the cylinders. The nature of the test to be applied depends on which of the two cases exists. It should be remembered that the timer closes the primary circuit four times during two revolutions of the crank-shaft in a four-cycle four-cylinder engine.

One way of connecting the primary circuit of an ignition system having four vibrating coils *a*, *b*, *c*, and *d* and two separate batteries is shown in Fig. 2. Each circuit can be tested in a manner similar to that described for a single-cylinder engine.

If the trouble occurs in all four cylinders, it probably is in the primary circuit and probably exclusive of the four wires

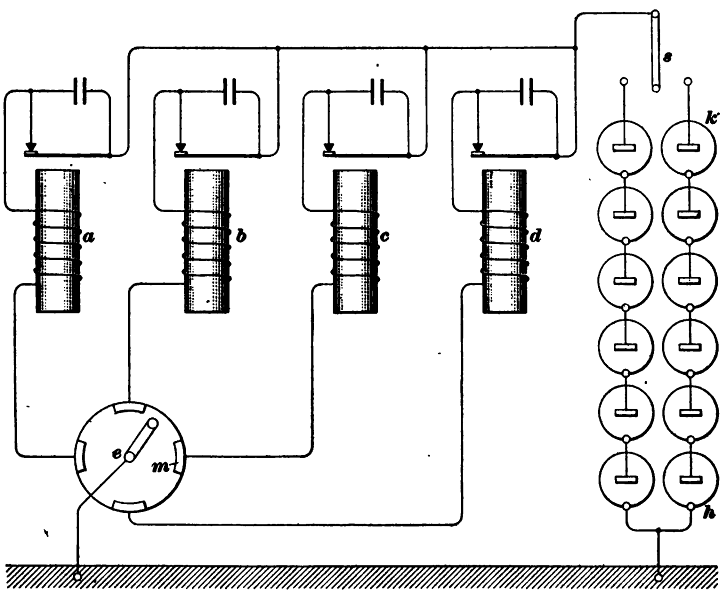


FIG. 2

that connect the timer to the coils. To test under this condition:

1. Switch the reserve battery, or put in a new one if there is the slightest doubt about the one in use being in good order.

2. Close the hand switch *s*, Fig. 2, or put in the plug that closes the primary circuit.

3. Examine the primary wire connections between the cells of the battery, between the battery, switch, and spark coil, and between the battery and the frame of the car.

4. Look for poor or chafed insulation and broken wires in the battery connections and in the wires leading from the battery.

5. Examine the timer for electric connection between its rotor *e* and the frame of the car. If the rotor is made up of a contact piece mounted on insulation, the screw that holds the parts together may be so loose as to make only intermittent contact.

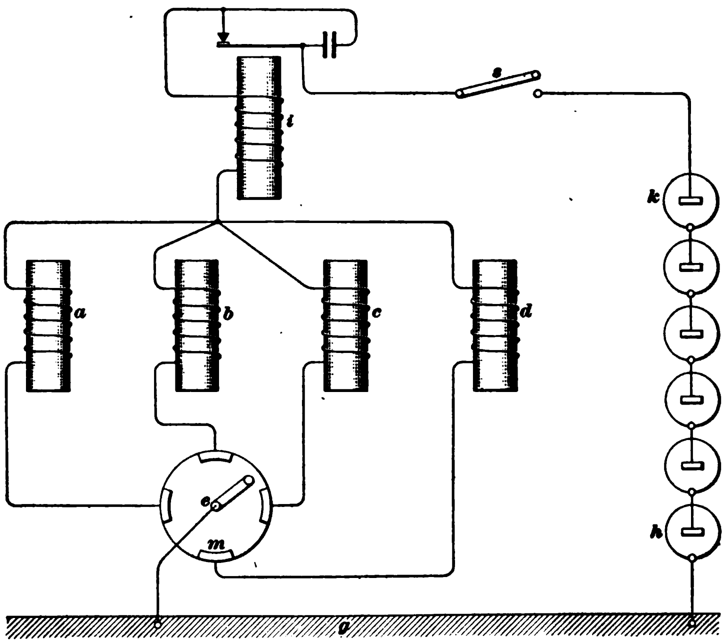


Fig. 3

6. If the engine will not run, each spark plug can be tested in succession by the methods given in tests 1, 2, and 3, Art. **44**.

47. In case the trouble is not in all the cylinders, and the engine will run by its own power:

1. Start the engine and hold down one or two of the vibrators at a time, so as to determine which cylinder or cylinders are not operating.

2. Proceed for each faulty cylinder in the manner described in Arts. **43** and **44.**

48. Any multicylinder engine with an ignition system having an individual spark coil for each cylinder may have its ignition system tested in a manner similar to that described in Art. **46** for a four-cylinder engine.

49. Testing an Ignition System Having a Master Vibrator and Individual Transformers.—In the ignition system in which an individual transformer without a vibrator is provided for each cylinder, and the vibrator of one master coil interrupts the current for all the transformers, the primary circuit may be connected as illustrated in Fig. 3. In this figure, the individual transformers are shown at *a*, *b*, *c*, and *d*; the master vibrator, at *i*; the rotating member of the timer, at *e*; one of the insulated metal segments, or contacts, at *m*; the car or engine frame, at *g*; and the battery, at *h k*.

If no spark is produced in any cylinder on account of ignition trouble, the fault is almost certain to be in the primary circuit, and probably exclusive of the wires connecting the timer to the transformers. If the vibrator sticks, the ignition will cease abruptly and completely.

50. In case all ignition stops:

1. Switch on the reserve battery, or put in a new one.

2. Press down the vibrator, and, if necessary, clean the vibrator contacts.

3. If the vibrator does not operate in test 2, short-circuit the timer by connecting a wire to the frame of the car and pressing its free end successively against the metal terminal, binding post, or bare wire attached to each transformer winding on the side connected to the timer. If the vibrator works for any one of these parts, the fault is due to a defect in the circuit that is short-circuited when the vibration occurs.

4. If no vibration occurs in test 3, examine the primary circuit, including the battery connections, the wires leading from the battery, and the ground connection at the timer

rotor. The examination should be made for loose connections, chafed or poor insulation, and broken wires.

5. The only remaining place for the fault is inside the case of the master-vibrator coil.

51. If the ignition is irregular, it may be due to a fault anywhere in the system. Tests to locate it can be made as follows:

1. Short-circuit the spark plugs, one or two at a time, while the engine is running, to determine whether the misfiring occurs in all the cylinders or in only part of them. No matter what kind of device is used for making this short circuit, it should have an insulated part that can be held in the hand. A screwdriver with a handle entirely of wood will answer. If the misfiring is in all the cylinders, first make the test given in Art. **50.**

2. If the misfiring occurs in some cylinders only, disconnect the wires from the spark plugs of the cylinders that misfire and place the ends of the wires within $\frac{1}{8}$ inch or less from the metal of the engine or car frame. Then rotate the engine slowly to determine which wire or wires do not spark across the air gap at the end of the wire.

3. Examine each high-tension wire that did not spark in test 2, in order to make certain that its insulation is good, that the wire is not broken, and that it is connected to its transformer properly. Then rotate the engine again and look for sparks at the wire ends as before.

4. With a wire, connect the car frame to the timer side of each transformer that does not spark, taking one at a time. If no spark is obtained, the fault is in the transformer, the master vibrator, or the high-tension wire.

If the master vibrator is connected between the car frame and the timer, the test wire should be connected between the wire leading from the master vibrator to the timer and each transformer in turn. If no spark is obtained, the fault is in the transformer, master vibrator, or the high-tension wire.

If the vibrator works properly when testing any transformer, the trouble is not in the master vibrator. If a spark

is obtained from a transformer that gave no spark when the engine was running, the trouble is in the timer or some primary wire loose enough to give trouble only when the engine shakes it.

5. If, in test 4, a spark is obtained when the engine is not running, then short-circuit from the car frame to the stationary contact of the timer that corresponds to the high-tension circuit that gives a spark. If a spark is obtained with the engine not running, the trouble is in the timer or in the wire from the timer to the frame; but if no spark occurs, it is on account of a fault in the wire from the timer to the transformer.

6. Put in a new spark plug or test the old one.

52. Testing a High-Tension Distributor Battery-Ignition System.—The test employed for an ignition system using a battery as a source of current and a high-tension distributor is practically the same as that used for a master-coil and transformer system; hence, the tests given for the latter can be applied by making only slight modifications to correspond to the different forms of apparatus and circuits. It is well to be certain that the insulation around the high-tension distributor terminals, past which the distributor arm swings, is entirely free from small particles of metal that may have been worn from the arm or the terminals.

TESTING JUMP-SPARK MAGNETO SYSTEMS

53. Testing a Non-Synchronous Magneto System. The magneto for jump-spark systems may be driven in synchronism with the engine by some positive drive, such as gears with teeth, or it may be driven by a belt, which, of course, does not keep the rotor of the magneto in synchronism with the engine. In the latter case, the magneto may be considered as a substitute for a battery, because the remainder of the ignition system is of such nature that either the magneto or a battery can be used to supply the current.

When a non-synchronous magneto is used to supply the current, the tests for faults can be made in the same manner as if a battery were used. These tests, however, do not include the test of the magneto itself.

54. Testing a High-Tension Synchronous Magneto System.—As a high-tension synchronous magneto ignition system consists of only a magneto, spark plugs, and high-tension wiring, the testing of such a system is a simple matter.

The series of tests that follows is especially applicable to an ignition system whose magneto is provided with individual socket connections for the spark-plug wires and has a window through which a spark at the safety gap can be seen. It is assumed that there is either a device for snapping the rotor of the magneto around so as to produce a spark when the engine is cranked slowly by hand, or else a battery and spark coil for producing a spark independent of the magneto when the engine is not running.

1. To determine which cylinder is not operating properly, pull the wires from their sockets one at a time while the engine is running. Sparks should appear at the safety gap of the magneto while the connection is thus broken. If the sparks appear regularly at the safety gap when the connection to a cylinder that misfires is broken, the fault is in either the spark plug or the wire connection of that cylinder. However, if the sparks do not occur regularly at the safety gap, the magneto is at fault.

2. If a spark appears regularly at the safety gap having a wire disconnected from its socket, disconnect the wire also from its spark plug while the engine is running, connect it to the magneto at the socket end, and hold the free end within $\frac{1}{8}$ inch or less from the metal of the engine. If a spark does not occur regularly at the end of the wire, the wire is at fault.

3. If a spark appears at the safety gap in test 2, stop the engine and remove the spark plug from the engine. Connect the plug and wire together. Place the outer metal of the plug against the engine and crank it. If there is no spark at the spark points of the plug, this plug is at fault.

4. Although a spark may be produced at the spark plug in test 3, yet a spark may not be produced when the plug is in the cylinder because the gas surrounding it is compressed. The plug may be still further tested if the contact points can be separated as far as $\frac{1}{8}$ inch. The proper distance between the spark-plug points for magneto ignition is about $\frac{1}{64}$ inch. Separate the points about $\frac{1}{8}$ inch and test again as in test 3. If a spark passes, again bring the points their proper distance apart before using the plug. It may be impossible to crank the engine fast enough by hand to produce a spark across the wide gap. This can be determined by disconnecting the wire from the plug and holding the end of the wire $\frac{1}{8}$ inch from the engine while cranking. In this case, reduce the spark gap until a spark will pass the gap between the end of the wire and the engine. Then adjust the distance between the sparking points of the spark plug to the width of gap just found experimentally and repeat the testing of the spark plug.

5. If, after all precautions have been taken, no spark passes the sparking points of the spark plug in test 4, clean the spark plug, taking it apart if necessary, and test again; if sparks still fail to pass, put in a new plug.

6. If sparks do not occur regularly at the safety gap, examine the contact points of the interrupter to determine whether or not they open the proper distance. Clean the contact points, and smooth and adjust them if necessary.

7. Examine the high-tension distributor for worn or loose parts. Clean it to remove particles of metal, carbon, or other matter.

8. If the magneto has collector brushes and other rubbing or moving parts, further examination of it should be made for worn and loose parts. The method of making this examination depends almost entirely on the form of the magneto, the instructions of the manufacturers and the judgment of the operator being the best guides.

9. A test for magnetization can be made by disconnecting the rotor from its driving mechanism and then turning the rotor by hand. The rotor should resist rotation for a part of a revolution and then be drawn forwards by the field magnets.

If its resistance to turning is not variable to a decided extent, the magnets are probably weak. This fault, however, is unusual.

55. The following tests apply especially to a high-tension magneto provided with individual socket connections for the spark-plug wires, but no window for observing a spark at its safety gap:

1. Pull the wires from their sockets one at a time when the engine is running, to determine which cylinder is operating properly.
2. With all wires connected through their sockets to the magneto, disconnect one wire at a time from its spark plug while the engine is running and hold the free end within $\frac{1}{8}$ inch or so from the metal of the engine. If a spark does not occur regularly at the end of the wire, either the wire or the magneto is at fault.
3. If sparking at the end of the wire does not occur regularly in test 2, substitute one of the other wires or, better, a wire known to be good, for the one just used. If a spark does not now occur regularly, the fault is probably in the magneto.
4. Make tests 6, 7, 8, and 9, Art. **54.**
5. If trouble still occurs and the magneto is in order, remove the spark plug from the engine, connect the wire and plug together, place the metal of the plug against the engine, and crank the engine. If there is no spark at the spark points of the plug, the latter is at fault, provided, of course, that the engine is cranked fast enough.
6. Make tests 4 and 5, Art. **54.**

56. The following tests apply to a high-tension magneto with neither sockets for spark-plug wires nor means of observing the spark at the safety gap:

1. To determine which cylinder is misfiring, short-circuit the spark plugs, one at a time, while the engine is running. Make the short circuit from the engine to the insulated part of the plug. The part of the metal used for short-circuiting that

is held in the hand should be insulated. If the trouble is common to all the cylinders, make tests 6 to 9, Art. **54.**

2. Either put a new spark plug in the cylinder that misfires or clean the old one.

3. Stop the engine and disconnect the wire from the spark plug of the cylinder that misfires. Fasten the end of the wire so as to hold it $\frac{1}{8}$ inch from the metal of the engine. Crank the engine if the magneto has a device for giving full-strength sparks while cranking it slowly. Otherwise, start the engine if possible. If a spark does not occur regularly between the wire end and the engine, either the magneto or the wire is defective.

4. If test 3 cannot be made, place the end of the wire $\frac{1}{16}$ inch or less from the engine and crank by hand as rapidly as possible. If no spark occurs with rapid cranking when the wire is fastened so as to be held as close as $\frac{1}{64}$ inch from the engine, the fault is in either the magneto or the wire.

5. Examine the wire for defective insulation or a break, and, if necessary, put in a new wire.

6. Examine the interrupter, distributor, and magneto as described in tests 6 to 9, Art. **54.**

57. Testing a Low-Tension Magneto Ignition System.—The following tests apply to an ignition system having a low-tension synchronous magneto with a high-tension distributor and timer, or interrupter, and a separate transformer, the latter being a spark coil without a vibrator:

1. To determine which cylinder is misfiring, either withdraw each high-tension wire in turn from its magneto socket or short-circuit the spark plugs one at a time. If misfiring occurs in all the cylinders, next make test 6.

2. Either put a new spark plug in the cylinder that misfires or clean the old one.

3. Disconnect the wire from the spark plug of the cylinder that misfires. Place the end of the wire $\frac{1}{8}$ inch from the metal of the engine. Crank the engine if it has a device for giving a full-strength spark while cranking slowly. If it has not this device, start the engine if possible; and if it cannot be

started, apply test 4. Sparks should occur regularly at the end of the high-tension wire.

4. If test 3 cannot be made, place the free end of the high-tension wire $\frac{1}{16}$ inch or less from the engine and crank by hand as rapidly as possible. Sparks should pass regularly at the wire end, especially if it is held very close to the engine.

5. If regular sparking does not occur in test 4, examine the high-tension wire for defective insulation or a broken wire.

6. If misfiring occurs in all the cylinders, disconnect the low-tension wire from the transformer spark coil. Crank the engine and at the same time rub the free end of the wire lightly against the unpainted rough metal of the engine or of the car frame, or hold it against the teeth of a rotating metal gear-wheel. There should be sparking, even at a comparatively slow speed of cranking.

7. If no sparks appear in test 6, examine the wire between the magneto and transformer for defective insulation, loose connections, and a break. Also examine in the same manner the ground wire between the transformer and the frame of the car.

8. Attend to the interrupter, distributor, and magneto in the manner described in tests 6 to 9, Art. **54.**

9. If trouble still continues, it is probably in the transformer.

58. The tests to be applied to a low-tension electric generator, including both synchronous magnetos and direct-current generators, when used in connection with a vibrator spark coil are of the same nature as when a battery is used, except that the test of the generator itself replaces that of the battery. The engine must, of course, either be running by its own power or be cranked fast enough by hand when making the tests that require electric current.

For a single-cylinder engine, all the tests given in Art. **43,** with the exception of test 5, which relates to the battery only, can be applied. This type of ignition circuit for a two-cylinder engine, with both spark plugs in series in the same high-tension circuit, can be tested as explained in Art. **45,**

and for any multicylinder engine, as described in Art. **46,** exclusive of the tests that relate to the battery alone. To determine whether the generator will furnish current, tests 6 and 7, Art. **57,** should be made.

59. Tests of Dual High-Tension Ignition Systems. The test of one system of a dual ignition system can be made by cutting the other out of operation. The method of testing is then the same as already given for a similar single system. It is generally convenient, however, to make use of a part of the second system during some parts of the test, as for instance, running the engine when it would otherwise have to be cranked by hand.

TESTING MAKE-AND-BREAK IGNITION SYSTEMS

60. The current for low-tension make-and-break ignition is generally supplied by an alternating-current magneto generator; but sometimes a direct-current magneto or a direct-current generator having electromagnetic fields is used. A battery is frequently provided for starting the engine. It should be immediately cut out when the engine begins to run. A test of the system in case of trouble can be made in the following manner:

1. Cut out the ignition from the cylinders, one at a time, to determine which one is misfiring. The ignition can be cut out by opening the circuit leading to the igniter. Individual switches are sometimes provided for this purpose. The wires can be disconnected without shock while the engine is running if care is taken. In any case, the shock will not be severe. The igniter should not be short-circuited to cut out the ignition.

2. Remove the igniter from the cylinder that misfires and clean its insulation. Smooth off the contact points if they are rough or pitted, and see that they are tight in place.

3. Look for loose connections, defective insulation, and broken wires in all the connecting wires, including those in the engine and kick coil.

4. Disconnect the wires from all the ingiters and rub the free end of one of the wires against the rough, unpainted surface of the engine or of the car frame while cranking the engine. Sparks should occur if the generator is in order.

61. If the generator is of the direct-current type, make the following tests:

1. Examine the commutator for a fused or a blackened segment. Either of these conditions indicates a loose connection, a short circuit, or a broken wire in the armature.
2. See that the commutator brushes have free movement in their holders; also, that the brush is not worn so short that the brush spring cannot press it against the commutator.
3. Test the brush spring for sufficient strength to hold the brush against the commutator.
4. Clean the commutator. Cleaning can be done by holding a piece of fine sandpaper against the commutator while rotating the engine by hand and afterwards removing the grease either with a piece of cotton cloth or a chamois skin.
5. If the commutator is out of round or is much grooved, it should be turned true in a lathe.

62. If a magneto is used, test it for magnetism by disconnecting its driving mechanism and then rotating it by hand. This rotation should be strongly resisted at regular intervals during a revolution. The periodical resistance to rotation is due to the pull of the magnet field.

63. The field magnets of a direct-current generator are always very weak when the generator is not running. They may lose their strength so that the generator will not pick up and produce a current when running. They can be magnetized by passing a battery current through the field coil while the engine is not running. If the generator is used for charging a storage battery, care must be taken to remagnetize it so as not to alter the polarity of the field poles, since otherwise the direction of the current produced may be reversed. If the direction of the current should happen to be reversed, it will be necessary to reverse the connections with the storage battery.

OVERHAULING AND REPAIRS

OVERHAULING

RUNNING-GEAR OVERHAULING

OVERHAULING THE STEERING MECHANISM

1. Testing for Looseness in Steering Knuckles and Front Wheels.—In order to examine the knuckle joint of the steering road wheels, one of the front wheels should be jacked up and shaken if possible, either by pulling the top back and forth or by lifting up on the hub or the bottom of the wheel. In this way, looseness in the swivel joint that connects the steering knuckle to the front axle will be disclosed. If it is found that the swivel joint is not loose, but the wheel shakes, then the looseness is in the bearings between the hub of the wheel and the spindle on which the wheel rotates. However, if the swivel joint is loose, as can be seen by the movement of the parts relative to each other, it will generally be difficult to determine at the same time whether the wheel is loose on the spindle bearings. A convenient method of testing for the latter looseness in case the swivel joint is loose is to drive a wooden wedge firmly between the fork in the end of the axle and the portion of the knuckle joint that fits in between the ends of the fork, so as to prevent any motion of the knuckle relative to the axle. Shaking the wheel will then show whether or not it is loose on its spindle bearings.

The repair for a loose swivel joint when pin connections are used is to bore out the holes and to put in a larger pin; or if bushings through which the swivel pin passes are used, to put in new bushings and a new pin. All these repairs are inexpensive compared with the cost of a new axle or a new knuckle joint.

2. **Examination of Front-Wheel and Knuckle-Joint Bearings.**—In order to examine the front-wheel and knuckle-joint bearings, it is first necessary to remove the front wheel. This can be done by unscrewing the dust cap at the outer end of the hub and then removing the locking pin or other device used to hold the ball bearing or roller bearing in place, assuming that one or the other of these devices is used. The dust caps on the hubs can generally be unscrewed, or loosened, by turning them in the same direction as that in which the wheel rotates when a car is traveling forwards. Sometimes, however, the dust caps on all the wheels are made with right-hand threads. In such cases, the caps on the right-hand side of the car, when one is sitting in the car and facing forwards, unscrew by turning them in the direction opposite to the rotation of the wheel for forward travel; but those on the left-hand wheels unscrew by rotating them in the same direction that the wheel rotates for forward travel. A cap that unscrews by turning it relative to the wheel in the opposite direction of the ordinary rotation of the wheel tends to work loose in case it strikes the end of the axle or any other part that does not rotate with the wheel. The nuts that hold the races and the wheel bearings in place, or in some cases the races themselves, are generally threaded so that they must be turned in the same direction as the wheel rotates in order to remove them. In some cars, however, a different practice is followed, namely, the nut or the race must be turned in the direction opposite the rotation of the wheel in order to remove it from the wheel.

In nearly all modern machines, the balls or rollers used in the wheel are held in retaining rings or cages, so that they will not fall out individually when the bearing is removed.

In some of the older cars, however, the balls are not held in place by a retaining ring, and for this reason they fall out when the parts are separated unless the bearing is packed with thick grease before entirely separating the parts. The method of holding the balls by packing them in heavy grease can be used when putting the bearing back into place.

3. If any of the balls of either bearing are found to be rough on the surface on account of the flaking off of some of the metal, an entirely new set of balls should be put in for that bearing, taking care to have all the balls of the same size. Whether or not larger balls should be used depends on the judgment of the inspector. If either of the races on which the balls run shows roughness of surface, also caused by the flaking of some of the surface metal, it is always advisable to put in new bearing rings. The next best thing to putting in new bearing rings is to regrind the old rings, but this operation is often as expensive as providing new rings. If the races are grooved by the wear of the balls, but are not rough on account of flaking, they can be used satisfactorily, provided the grooves are not deep. However, it should be remembered that the wear is likely to be very rapid after the grooves in the races become large enough to be visible.

Both front wheels should be examined in the manner just described. The rear wheels also should be examined for the condition of their bearings, provided they run on an extension of a solid rear axle, as is the case with machines that use side chains for transmitting the power to the driven road wheels.

4. If the knuckle joints are supported on adjustable ball bearings, or if the bearings are of the cup-and-cone type, so that they can be adjusted for wear, an attempt should be made to make such an adjustment; but if there is still a shake in the swivel joint after such an adjustment, the joint should be taken apart and the bearing parts examined for wear. It is always a good plan to separate such parts and clean them carefully, even though they do not show lost motion on account of wear, and then to test them for accuracy of fit after reassembling.

5. Examination of Distance-Rod Joints.—The test for lost motion in the distance rod that connects the arms of the steering knuckles can be made while one of the steering wheels is lifted free from the ground. The test consists in simply shaking the wheel back and forth in a direction at right angles to that in which it travels, and at the same time watching for lost motion at the connections between the distance rod and the arms to which this rod attaches. If lost motion is not noticeable to the eye, a closer test can be made by holding the hand on the connections while shaking the wheel in the manner just stated. It is well to clean the joints before making the test.

The remedy for lost motion in the pin-connected joints is to ream out the holes and to put in larger pins. Many distance-rod joints, however, can be tightened by simply turning a nut or some other device, in which case the tightening is merely a matter of adjustment.

6. Testing for Lost Motion in Steering Gear and Reach Rod.—In testing for lost motion between the hand wheel for steering and the steering knuckles, the knuckle joints are wedged tight with wooden wedges, and a stick of wood is also wedged in between the arms of the steering knuckle so as to press the parts firmly together at the joints where the distance rod connects with the arms of the steering knuckle. Then, by turning the hand wheel back and forth while the front wheels rest on the ground, the amount of lost motion between the hand wheel and the knuckle joint can be determined. An examination of the connection of the reach rod to the steering knuckle will show whether or not any lost motion exists there, and a similar examination at the joint where the reach rod connects to the crank-arm of the steering mechanism that lies at the lower end of the steering column will show the condition of that joint.

7. A test for lost motion in the mechanism of the lower part of the steering column can probably be made best by disconnecting the reach rod from that mechanism and then pulling the crank-arm back and forth in the direction that it

moves when operated to steer the car. This test should be made for several positions of this arm, from one extreme position to the other. It frequently happens that the arm will have considerable lost motion when in the position for running the car straight ahead, but will have little or no lost motion when moved to one or the other of the extremes of its travel. If a worm and worm-wheel are used for moving the arm, this condition can in some steering mechanisms be remedied somewhat by turning the worm-wheel around half way or so on its shaft, relative to the position of the crank-arm on the same shaft. Many worm-steering mechanisms have only a sector of a worm-wheel, however, and therefore there can be no such change of position of the worm-wheel sector on its shaft as when there is a complete worm-wheel.

The lost motion is often due to wear of the threads of the worm that is attached to the steering column. It may be possible in such a case, even though the worm-wheel is only a sector, to move the worm-wheel sector far enough relative to the oscillating crank-arm to which the reach rod is connected to remedy in a measure the inequality of lost motion just mentioned. Lost motion is also frequently due to wear of the bearings that support the worm-wheel or sector shaft. In such a case, new bushings may prove a remedy, but the shaft must be turned or ground before the bushing is fitted. The bearings of the steering column itself may have worn, and the worm may have considerable end play. In some steering gears means are provided for adjusting the distance between the worm and the worm-wheel or sector, and considerable lost motion between these two parts can then be readily taken up by proper adjustment.

There are some steering gears in use in which no adjustments, or, at best, but one or two, are possible; in such cases, new parts must be substituted for the worn ones.

8. Test of Steering Mechanism After Overhauling. After all replacements and adjustments have been made on the steering gear, distance-rod joints, reach-rod joints, and steering knuckles, it is well, as a final test, to see whether or

not the steering mechanism is all right. In order to make this test, the front axle should be jacked up until both front wheels clear the floor. With the hand steering wheel, the road wheels should be swung from one extreme position to the other, and attention should be paid as to whether or not any of the joints or parts bind. If there is any binding, it indicates that there is too close an adjustment somewhere. The wheels should swing perfectly free through their whole range of movement. Binding will most likely occur as the wheels near their extreme positions, and is usually due to ball joints that have worn out of round. If this is the case, either the adjustments must be eased or the parts must be repaired or replaced.

9. Testing of Front Wheels for Parallelism.—Any lack of parallelism of the front wheels, when set for driving straight ahead, will give the tires a sliding instead of a true rolling action, resulting in rapid wear of their treads. Hence, it is well to test the front wheels for parallelism as a conclusion to the overhauling of the steering mechanism. To do this satisfactorily, a pair of wooden calipers like that shown in Fig. 1, may be improvised. The calipers shown consist of three strips of wood about 3 in. × $\frac{3}{8}$ in. These are nailed together as shown, and two round-headed wood screws *a* are set into the ends of the legs *b*.

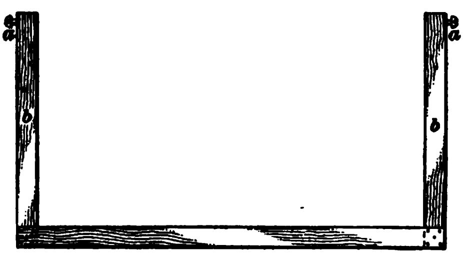


Fig. 1

The front wheels having been set for driving straight ahead, as near as can be judged by the eye, the calipers are set to the distance from rim to rim at the front of the wheels and at the same height above the floor as the center of the wheels. The calipers are then moved to the rear of the wheels and the distance from rim to rim tested at the same height above the floor. If the wheels are parallel, the distances from rim to

rim will be the same; if they are not parallel, the distance rod joining the steering knuckles must be either lengthened or shortened.

REAR-AXLE OVERHAULING

10. Overhauling a Shaft-Drive Rear Axle.—The driving mechanism in the rear axle of a car having shaft drive and differential gears in the housing of the rear axle can be first tested roughly for wear and lost motion by attempting to give a rocking motion to the shaft that extends forwards from the pinion of the bevel gears. This test can sometimes be made by applying an ordinary wrench to the rear half of the universal joint, which is fastened to the shaft. However, it may be necessary in some cases to clamp a piece of wood or iron on the end of the shaft in order to give it motion. A still further test is to jack up one of the rear wheels, and then, while holding the shaft so that it cannot rotate, as by means of a wrench or a clamp in the manner just mentioned, rotate the elevated rear wheel back and forth to determine the amount of motion that can be given to it without moving the driving shaft or the other rear wheel.

Lost motion found in either of the two tests may be due to looseness between the driving wheels and the axles that support and drive them, or to looseness between the road wheels and the floating axles that drive them. It may be possible to determine whether such looseness exists by removing the dust caps from the driving road wheels, letting both wheels rest on the ground, and then rocking the shaft back and forth, noting in the meantime whether the axles have any rotary movement in the wheels, or, if a floating axle with a clutch for each wheel is used, whether there is any lost motion between the clutch and the road wheel.

Ordinarily, the next step would be to remove the driving wheels in order to test and examine the bearings upon which they or the driving axle that supports them rotate. A test for looseness of a live driving axle with regard to the dead tubular axle inside of which it runs, can first be made by attempting to shake the projecting end of the axle up and

down and sidewise. This will generally show any looseness sufficient to require repair in this part of the car.

If races are supplied for either ball or roller bearings used to support the axle, they can generally be removed and replaced by new ones. In some cars having live axles and roller bearings, there is no outer or inner race provided for the rollers, and the rollers run directly on either the inside of the rear axle tubing or the outside of the driving axle. If the axle tubing or the axle is badly worn, about the only practical repair to make is to put in new tubes or new axles. In case of the axle tubes, it is sometimes possible to rebore them and then fit bushings; but in case of the axles, repairing is usually inadvisable and in most cases impossible.

11. The rear axle may next be taken apart at the housing that encloses the differential gears. The ends of the half axles next to the housing can then be tested for looseness in the bearings by shaking, and, if necessary, they can be removed for an examination of the bearings. These bearings should be kept in good order and should be a good running fit, because it is necessary to keep the pinion that is driven by the driving shaft in proper alinement with the large bevel gear.

The thrust bearing, which takes the thrust of the large bevel gear in the housing, should also be kept in good condition. If there is any wear that allows the large bevel gear to move in a direction that tends to separate it from the teeth of the pinion that drives it, then the bevel gears will not mesh together properly, and the result is rapid wear, generally accompanied by much noise.

The bearings of the shaft that carries the bevel pinion enclosed in the axle housing should also be very carefully examined for wear. In propeller drives having a universal joint at the rear axle, this shaft is usually so short and the bearings that support it are frequently so close together in consequence of its shortness that they are liable to wear rapidly. Even a small amount of wear in bearings located as closely together as they frequently are on this shaft will allow the

bevel pinion to move considerably out of its proper position relative to the bevel gear that it drives. The result is the same as when the large gear gets out of position, so far as rapid wear and noise are concerned.

The method of repairing these bearings depends on whether they are of the journal type or have balls or rollers to run on. If the bearings are much worn, it is usually advisable to substitute new ones, because the service required of them is such as to cause rapid deterioration after appreciable wear has taken place; besides, wear in this place is likely to cause serious results if allowed to become excessive.

12. The pins on which the intermediate gears of the differential run, or the holes that form their bearings, together with the intermediate gears themselves, should be examined for looseness. Although a little play in these gears is generally not a serious matter, since they do not revolve very much, it is desirable to have as good a fit here as elsewhere. It should be noted whether the gears of the differential that are fastened to the half axles are rigidly and firmly connected to them. If there is any looseness of connection, it should be eliminated, because looseness at this point causes heavy stresses in the transmission system when a clutch is thrown into engagement for starting the car. The same thing is true of lost motion in any part of the transmission system.

13. The method by which the differential housing can be opened depends on its design. In many of the modern cars it is possible to remove a part of the housing on one side of the axle without disturbing either one of the half axles or the connection between the two. In some designs of axles, gears can be removed while the two ends of the axle housing are still rigidly fastened together. In fact, some rear-axle housings are made in one solid piece, including the differential housing; a part of the differential casing is then removable from the side of the housing. This cover is generally located at the top or between the top and rear part of the housing.

In most of the earlier types of cars, the differential housing is in halves, divided perpendicular to the length of the axle.

Such axles generally have to be taken completely apart to reach and inspect the differential gears.

14. Overhauling a Double-Chain Rear Axle.—Owing to the fact that the rear axle of a car having a side chain drive is solid, about all that has to be done is to see that the axle is not bent and to examine the wheel bearings by removing both rear wheels. The nuts of the spring clips should be tried, and, if necessary, they should be tightened. While the rear wheels are off, an excellent chance is presented to examine the sprockets, the brake drums, and the brakes, all of which should be repaired or replaced before reassembling. Since, as a general rule, the differential gear is incorporated in the transmission, it would naturally be overhauled together with that mechanism.

15. Overhauling a Single-Chain Rear Axle.—In cars driven by a single chain, the differential is incorporated in the rear axle, the differential drum carrying the rear sprocket. In many cases the service brake is also applied to the differential drum. When the rear axle is taken apart at the differential housing, the wheels having been removed previously, the half axles can usually be removed and an examination of their bearings made. The differential gear, as well as the sprocket, the brake drum, and the brake band, may also be examined at this time.

OVERHAULING OF MISCELLANEOUS PARTS

16. Overhauling of Chains and Sprockets.—The transmission chains and the sprocket wheels on which they run should be examined for wear. Probably the best method of examining a chain for wear is to remove it from the sprocket wheels and clean it in gasoline or kerosene, making sure that all dirt and grease are thoroughly removed from between the pins and the holes in the links. Then it can be inspected for wear by taking each adjacent pair of links in the hands and working each pair back and forth in order to determine the

amount of lost motion. It may be found that while only a slight amount of wear is indicated by this lost motion in most of the links, there may be one or two links that are very much worn. The pins should be removed, and either new pins or both new pins and new links substituted.

One of the best methods of lubricating a driving chain after it has been cleaned, inspected, and repaired, is to place it in a shallow pan filled with molten mutton tallow and allow it to remain there for half an hour or more. After keeping the chain in the molten tallow for this length of time, it may be removed from the pan and hung up while hot, and the surplus tallow allowed to drain off.

A chain will run successfully, so far as strength is concerned, after considerable wear has occurred in its joints. The wear of the joints, however, increases the length, or pitch, of the chain and destroys its proper engagement with the sprocket wheels. A chain whose pitch has been increased by wear engages with the sprocket wheels in such a manner that, on the driving sprocket, only the links that have last wrapped on the sprocket bear against the teeth of the sprocket. On the driven sprocket wheel, only the links of the chain near the point where the chain leaves the sprocket wheel engage with the teeth of the wheel when the chain has become much elongated, or increased in pitch, by wear.

Another method of examining the chain for wear in the pin joints and on the portion of the links that bears against the sprocket wheel, is to wrap the chain around the sprocket wheel, pulling it tight in one direction, and then examine each link and adjacent sprocket tooth with regard to the space between them. When examining a chain in this manner, only a comparatively short section of it will have to be examined at a time.

17. The teeth of the sprockets should be examined for excessive wear on their driving side; that is, the side against which the chain bears when the car is going forwards. A good idea of the amount of wear can be obtained by comparing the tooth outlines on both sides. The side against

which the chain bears while the car is being driven backwards will show but little wear.

In some cars, both the driving and the driven sprockets are reversible; that is, they can be turned around so that what was the side of the tooth for going ahead can be made the side for going backwards, thus giving a good tooth outline for going ahead.

18. Generally speaking, when both sprockets and the chain have worn considerably, the sprockets, as well as the chain, should be replaced. Putting a new chain on worn sprockets or a worn chain on new sprockets, will give rise to great friction losses and thus retard the speed and diminish the hill-climbing ability of the car.

19. Overhauling of Universal Joints.— Universal joints in the transmission system, when between two shafts making a considerable angle with each other, are apt to wear with great rapidity unless they are of excellent construction. A universal joint, no matter where it is located, should be examined and tested for wear between the parts that move over each other during the operation of the joint. If the forks are connected by pins without roller bearings, then the wear between the pins and the forks is sometimes extremely rapid; and after the pin has become very loose in the holes into which it fits, the material surrounding the hole, if of the soft quality that is sometimes used for such couplings, may even become so battered as to flange or fin out at the ends of the hole. The forks of the universal joint should also be examined for looseness on their shafts if they are not brazed or welded to them.

20. Overhauling of Brake Drums.—The brake drums, especially those on the rear wheels, should be examined for the thickness of metal, and also for cracks in case the drums are of cast metal. Cast iron and malleable iron are sometimes used to make brake drums. Such drums may crack after becoming worn thin, especially if an expanding brake is used. If the brake drum has no bead at the edge for retaining the

brake shoe in place, then its thinness can be readily detected by observation. However, if the drum has a bead, either for retaining the shoe in position or for strengthening the drum, it will have to be tested for thickness with a pair of calipers or some other suitable tool. Calipers of the type that are provided with an arc and a pointer back of the joint for indicating the distance between the contact ends of the caliper arms are suitable for an examination of this kind. A micrometer caliper can be used, but an instrument of such accuracy is not required.

21. General Inspection.—Wherever any of the parts of the operating mechanism come into accidental contact with other parts on account of vibration or rubbing, an examination should be made to determine whether the wear has been sufficient to weaken them unduly. This remark applies to such parts as brake rods, steering-gear mechanism, gasoline and water pipes, etc. The examination should also include a search for short bends or kinks in tubes or packing. A close search should be made for cracks and nicks in such parts as the arms of the steering knuckles and at the lower end of the steering column. The springs that support the body of the car should be inspected for cracks or breaks, and the parts that connect the springs to the body, such as clips and gooseneck extensions of the frame of the chassis, should also be examined. A general inspection should include all parts that are liable to fracture on account of the stresses to which they are subjected. The clips that hold the body springs to the axles of the car should be examined for looseness and cracks. It is especially desirable to have the springs firmly and strongly fastened to the axles.

OVERHAULING THE POWER PLANT

OVERHAULING THE ENGINE

22. Examination of Cylinders.—In order to examine the inside of the cylinder, it must be opened up in some manner. There are three types of engines in common use as classified with regard to the method of getting access to the inside of the cylinder. In one type it is necessary to remove the bolts that fasten the cylinder or cylinders and the crank-case together, and then lift off the cylinder. In another type, the pistons are removed from the cylinders by taking off the lower part of the crank-case, removing the caps (on the under side) of the main bearings, and then taking out the crank-shaft and pistons together. The connecting-rod can be removed from the crank-shaft before taking it out if desired, thus leaving the pistons in place to be removed one at a time after taking out the crank-shaft. In the third type of vertical-cylinder engine, the cylinder heads are removable as one piece from all the cylinders, thus exposing the valves, the top of the piston, and a part of the cylinder bore to view.

When it is necessary to remove the cylinders from the crank-case to gain access to the piston and interior of the cylinder, ordinarily, the first step is to remove the connections of the inlet pipe and exhaust pipe. Both the inlet and exhaust pipes, or manifolds, are often held in place by the same yokes and bolts. In such cases, both are removed at the same time. When they are separately bolted on, generally either one can be removed first; but, sometimes, when both are on the same side of the engine, they are so situated relative to each other that only one of them, as the exhaust pipe, can be removed first. The spark plugs should be removed before taking the cylinders from place. When removing the cylinders by lifting up, care should be taken not to allow the pistons and connecting-rods to fall to one side against the crank-case and strike so as to injure the pistons by indenting or nicking the edges at the lower, or inner, end.

Although the plan of removing the pistons by taking out the crank-shaft and then withdrawing the pistons from the lower end of the cylinders may be no more difficult than to lift the cylinders up from the crank-case, it is generally not so easy to inspect the interior of the cylinders while they are in place on the crank-case, where they are left after removing the pistons from the bottoms. Thus, it is probably as well, unless the complete engine is removed from the automobile, to take the cylinders off from the top, even in an engine that is designed so that the pistons can be removed with facility through the crank-case.

Engines in which the cylinder heads can be removed are generally so constructed that the barrel, or body, of the cylinder can be separated from the crank-case in the manner common to engines whose cylinder heads are integral with the barrel, or body, of the cylinder. The cylinder can therefore be exposed for examination in the same manner as if the cylinder heads were integral with the valve.

23. After removing the cylinders, they should be inspected in the bore for grooves and other signs of cutting and abrasion. When in proper condition, the bore is smooth and polished. The bore of a cylinder may also be tested for uniformity of diameter, or, more properly, for the proper taper. The cylinders of most automobile engines are bored slightly tapering, so that the bore is smaller at the head end of the cylinder than at the end that comes next the crank-shaft. This taper allows for the greater expansion that occurs in the head end of a cylinder while the engine is operating than at the crank end. The greater expansion, or increase of diameter, at the head end is due to the higher temperature of the cylinder at that end while the engine is operating.

A test of the diameter and roundness of the cylinder bore can be made with an ordinary pair of inside calipers, such as are used by machinists; or, a heavy wire or light rod of metal can be finished off smooth on the ends, as by a dead smooth file or an oilstone, to such a length that it will fit in the bore of the cylinder with its ends against diametrically opposite

points of the cylinder wall. This solid caliper must be made just long enough to allow it to go into the smallest diameter of the cylinder bore, as found on applying it to the cylinder in different parts. It can then be readily determined whether or not the bore is smaller at the head end, as it should be when the cylinder is cool.

A cylinder that is found to be of uniform diameter from end to end in its bore will generally operate with entire satisfaction, but it should be examined again after an ordinary season of service in order to determine whether or not it has become larger at the head end. Even when in this condition, it may operate satisfactorily; but, ordinarily, it should be rebored or ground when this condition is reached, provided the thickness of the metal that forms the cylinder walls is sufficient. If the cylinder bore is scored, it should be rebored or ground if possible.

24. Instead of using the ordinary machinist's calipers, or the solid wire finished to a proper length, an inside micrometer caliper can be used. The micrometer caliper will be found more convenient by persons familiar with such tools, and it will give the exact variation of the diameter in different parts.

Another method of measuring for variation, or uniformity, in the diameter of the bore of the cylinder is to insert a piston ring in the cylinder. Thus, as the ring is pushed through the cylinder from end to end, a variation in the circumference of a bore of a cylinder will be indicated by an equal variation in the distance between the ends of a ring. A lack of roundness in a cylinder, however, will not be indicated by this method. The ring when used in this manner must always be kept so that every point in one side or one edge of it is at the same distance from the finished end of the cylinder. In other words, the ring must be kept at right angles to the axis of the bore. The crank end of the cylinder is generally turned, or faced off, at right angles to the length of the cylinder bore. The correctness of the position of the piston ring can be tested for each of its positions by measuring from its side to the end of the cylinder.

25. The inside of the cylinder, including the combustion chamber and passages leading out to the valves, if there are any, should be scraped or otherwise cleaned to remove any carbon deposit present. If thought necessary, the cylinder can be tested hydraulically for cracks, porosity, or leaks at plugs that are intended to remain permanently in position. If the cylinder is rebored, a new piston and piston rings are necessary.

26. Examining the Piston and Connecting-Rod. One of the next steps to be taken is to examine the crankpins and their bearings for lost motion. This is done by shaking the wristpin end of the connecting-rod in the direction of the crank-shaft center line. The connecting-rods can then be removed from the crank-shaft by taking out of each the capscrews or bolts that fasten the cap to the main body of the connecting-rod. In some engines, the capscrews can be reached by first removing a plate from the side of the crank-case, such plates being provided in some engines for this purpose; otherwise, it will generally be necessary to get at the cap-screws and connecting-rods from beneath the engine. In a vertical engine, this can be done after the lower part of the crank-case has been removed; in a horizontal engine, the connecting-rod capscrews are ordinarily easily reached by removing a top cover-plate from the crank-case.

If the connecting-rods are found to be loose on the crank-pins, or if the crankpins or their bearings are cut and scored, they should be refitted and otherwise be put in good condition.

The piston pin can be tested for looseness in either the piston or the end of the connecting-rod, according to which it moves in. The pin is apt to wear out of round. If there is no means of adjusting for such wear, the looseness can sometimes be reduced somewhat by turning the pin one-quarter turn around in the part in which it does not move when operating. When the pin runs in a bushing or in bushings, these and the pin can generally be readily replaced by new ones.

27. Examining the Piston Rings.—The piston rings should be examined for scoring or grooving. If they are gummed in their grooves by carbon and residue of oil, they

should be cleaned. A ring that is bright on only a part of its outer surface, which is an indication of only partial contact with a cylinder bore, should either be peened or otherwise treated so as to fit properly. A ring that is loose sidewise in its groove should be discarded, and a new one that is wide enough to fit the groove properly should be substituted for it. If the grooves are worn so as to have decided shoulders, they should be turned in a lathe so as to have a rectangular cross-section.

28. Crank-Shaft Examination. — The crank-shaft should be tested for lost motion both sidewise and endwise in its bearings. If the bearings are of the plain journal type and are worn so that there is a great amount of lost motion, or so that the linings of the boxes are worn much thinner in some places than in others, it is generally advisable to put in new linings; but when the wear is not excessive, either the method of planing off the edges of the box linings where they come together or that of removing shims, if any are used to tighten the box on the journal, is generally suitable.

In the case of ball bearings on the crank-shaft, the method to be employed to take up lost motion will depend on the kind of bearing that is used. If the rings that form the races for the balls are solid and are not worn much, the lost motion can sometimes be taken up by substituting a new set of balls of a slightly larger diameter than that of the old balls. More than ordinary care should be taken to determine whether all the new balls are of the same diameter; they should not vary more than .0002 inch. If the raceway is roughened, even to a very slight extent, the safest and most advisable plan is to put in a new race and new balls. In other words, an entirely new ball bearing should be put in if there is any indication of roughness in the raceways.

29. Examination of Cam-Shaft Gears.—The system of gears used to transmit power from the crank-shaft to the cam-shaft and timer, or both systems when separate gear-trains are used for the cam-shaft and for the timer shaft, should be examined for wear. The general appearance of

a gear that is worn so that it should be removed is such as to indicate readily such a condition. The points, or tops, of the teeth will be much narrower than those of the gear that has not been worn much, and there will generally be a decided shoulder near the bottom of each tooth on one side of the space between adjacent teeth.

The gears can be tested for lost motion by shaking them back and forth, as by taking hold of the one that is attached to the cam-shaft and moving it back and forth in a rotary direction. If the gears are in what is termed ordinary good condition, the shake obtained in this manner will not be more than half the width of the top of the tooth that has been only slightly worn. When gears are new and properly fitted, there is scarcely any noticeable shake in gears used for such service as that of driving the cam-shaft of the engine. Although lost motion between the crank-shaft and cam-shaft is decidedly undesirable, especially when it becomes great, it is still more undesirable between the crank-shaft and the shaft of the spark timer. If there is lost motion between the crank-shaft and the spark timer, the time at which the electric circuit is closed for forming the ignition spark is likely to vary. At times, the lost motion will allow the timer to move ahead to the extent of the lost motion, but most of the time it occupies the position relative to the crank-shaft that it takes when power is transmitted from the crank-shaft to the timer shaft.

30. Examination of Cams.—The cam-shaft should be removed, provided this can be done without an excessive amount of labor. Most modern engines are made so that the cam-shaft can be readily removed, but in some of the earlier types the task of getting it out of place is arduous. At any rate, the cams should be examined for wear, although it is often difficult to determine whether they have worn. A reliable way of determining whether or not the cams have the proper form is to employ the valve-timing tests.

31. Examination of Valve Push Rods.—The push rods that lift the inlet and exhaust valves should be

examined at the ends that bear against the cams, especially if rollers are used in these ends. The rollers should be examined for roundness and also for lost motion between them and the pins on which they run. If there is any lost motion at the pins, it should be taken up either by putting in new pins and rollers or by enlarging the holes in the old rollers and putting in larger pins. As the rollers and pins are generally hardened, it is customary to put in new ones. However, in case new ones cannot be obtained, the temper of the rollers can be drawn so as to make them soft enough to be bored out, after which they can be rehardened and tempered. A new pin can be made of the proper size and then hardened and tempered.

32. Examination of Valves and Valve Springs. Both the inlet and exhaust valves, especially the latter, as well as their seats, should be examined for pitting. If pitting and also scoring are found, the valves must be ground to their seats. The springs on the exhaust valve and inlet valve of each cylinder should be examined for wear and strength. They can generally be tested satisfactorily for strength by lifting the valve by hand against the resistance of the spring when the parts are in place. An examination of the keys in the valve stems and the holes in which the keys fit should be made with regard to wear of these parts. This examination involves the removal of the keys at least part way. There is generally no injurious wear on the valve spring unless it rubs against some part with which it should not come into contact.

33. Examination of Flywheel.—It is well to examine the bolts that fasten the flywheel to the flange of the crank-shaft, in order to see that they are perfectly tight. This can be done by applying a wrench to the nuts on the bolts, first removing the locking device that holds the nuts in place. If the flywheel is keyed on the shaft, as in some of the earlier types of automobiles, it is well to test for looseness of the flywheel on the shaft.

OVERHAULING OF WATER AND OIL PUMPS

34. The pumps for both the cooling water and the lubricating oil should be examined for wear and lost motion. In these pumps, the journals and their bearings are the parts that generally wear more than any other members. The oil pump is not so much subject to wear as is the water pump. If the journals and bearings of the pump shaft become worn considerably, then the rotor of the pump may also be worn on account of rubbing against the side of the casing. If the rotor becomes much worn, it will not cause the water to circulate as rapidly as when it fits properly in the casing. Therefore, in case of a great amount of wear on the side of the rotor of a water-circulating pump, it is advisable to put in either a new rotor or a rotor and such parts of the casing as will make the fit between the rotor and the casing tight enough not to allow much eddy circulation of the water in the pump. Lost motion in the gears that drive either the water-circulating pump or the oil pump does not cause any appreciable trouble.

EXAMINING A CLUTCH

35. The examination of a multiple-disk clutch is ordinarily a matter of observing how much the disks are worn; but it is also desirable to open up a clutch that has been used for some time in order to remove foreign matter, including metal particles worn from the disks, that may have collected inside the casing. On account of the many designs of disk clutches, it is not possible to give any detailed instructions about taking them apart. It should be noted that the tendency of the closing spring to expand or otherwise gain its unstressed form may cause severe injury to the person that is removing the part that holds it in place, unless due provision is made for the sudden snapping free of the spring. Some clutches are so constructed that the friction disks can be removed without affecting the spring that fastens them together; but others are of such form that the spring must be allowed to take its unstressed form before the friction

disks can be removed. The only safe method for the inspector to follow is to study the construction of the clutch, and then proceed accordingly with due regard to the controlling of the action of the closure spring.

The disks of a multiple-disk clutch generally wear most rapidly at the edge farthest from the part that supports and drives them. They can therefore be used until this edge becomes very thin—even worn down almost to a knife edge in some cases. If all the disks were originally of the same thickness, the allowable wear for each disk would be half its original thickness. When this much has been worn away uniformly over the bearing surface, the adjacent disks that form one set, as the inner or outer set of disks, will come into contact with each other at their unworn surfaces, thus preventing pressure against the intermediate disks of the other set. The feather keys or grooves that engage the disks and drive them, or by means of which the disks drive a part to which power is transmitted, sometimes wear in notches where the edges of the notches or projections of the disks press against them. This kind of wear prevents quick opening of a clutch when it is disengaged, and causes drag. The worn notches should therefore be removed from the feather keys or grooves with which the disks engage.

36. With leather-faced cone clutches, it is difficult to tell how they operate without trial; yet, if the leather facing is so thin that it allows the cone to enter so far that the inner cone strikes against the back of the outer cone, or if the leather is very much glazed and shows evidence of charring from overheating, then a new leather should be put on. The condition of the leather cannot generally be determined without at least partly separating the friction members of the clutch. In doing this, the same precautions must be observed in regard to the closure spring as with disk clutches

37. Expanding and contracting clutches whose friction surfaces are cylindrical, need examination chiefly with regard to the remaining amount of adjustment that can be made to keep them in proper operating condition. If the friction

parts have worn so that very little adjustment remains, it is generally advisable to renew or repair the friction members so as to secure means of making nearly the full range of adjustment and thus allow for future wear.

38. The yoke and bearing used to release cone and disk clutches should be examined for wear. When constructed in such a manner that they cannot be kept well lubricated all the time, the wear on such thrust bearings is sometimes very rapid. Plain thrust bearings especially are apt to cut out in a very short time. When a ball bearing is used to take the thrust of releasing a clutch, the condition of the balls and races should be determined, the examination being for the same indications of wear as in any other ball bearing.

EXAMINING OF CHANGE-SPEED GEARS

39. Sliding change-speed gears can be examined for lost motion by removing the cover of the transmission-gear case, shaking the gears back and forth in regard to each other, and testing them in this manner for the settings corresponding to all the different speeds forward and the reverse. A more searching method of testing the change-speed gears for lost motion is to fasten one of the transmission shafts that extends from the case so that it cannot rotate even to the slightest extent in either direction. This can be done by applying a wrench or a clamp tightly to it and holding the handle of the wrench or the clamp down against some part of the frame of the car. Then, by rocking the other projecting shaft back and forth, the amount of lost motion can be readily determined for the corresponding setting of the gears. This test should be made for all the settings for the different speeds and the reverse.

Gears in the transmission case should be tried for looseness on their shafts or on the shaft flanges to which they are bolted. In many of the high-priced modern cars, the gears in the transmission case are fastened to flanges on the shafts by means of several bolts. These bolts should be examined

individually to see that they are tight. In some designs it is common for them to work loose and drop out into the gear-case; this is very dangerous on account of the possibility of a bolt being caught between the teeth of intermeshing gears.

In case a change-speed gear that is keyed to its shaft has become loose, a new key must be fitted. If a gear has been loose for some time on its shaft, both the gear and its shaft will have become so worn that it is impossible to make them fit properly together again without reboring the gear and bushing it. Any attempt to hold the gear tightly in place by simply driving in a new key will cause it to run out of true, and the gears, if they operate at all, will indicate the fact that at least one of them runs out of true by the production of a regular but intermittent noise.

40. The journals of the shafts in the change-speed gear-case, as well as the bearings that support them, should be examined for looseness. This can be done by shaking the shafts by hand. When making this test, the bearings should be as free as possible from oil or any other lubricant. The construction of the bearings in transmission-gear cases is generally such that a new bearing has to be provided when one becomes worn so as to cause much looseness of the journal in it. Of course, the new bearing may have to be smaller in bore than the old one was when new, in order to make up for wear on the journal of the shaft.

41. In a sliding-gear change-speed transmission, the yokes or other devices used to shift the gears by sliding them along their shafts should be inspected for tightness on the bars, or rods, to which they are attached. Inspection should also be made for looseness of the yokes, or fingers, in the grooves that form a part of, or are connected to, the sliding members of the gear-set. The sliding members of the gear-sets should also be tested for lost motion endwise on their shafts for each setting of the change-speed lever that corresponds to an operating position of any group of the gears in the transmission case. It is also well to test the sliding members for endwise lost motion when they are in their

neutral positions. The object of this test is to find whether any of the sliding members have enough end play, when set in neutral position, to rub against the rotating parts adjacent to them.

It frequently happens that the yokes used for shifting the sliding members become so loose and worn upon the shifting rods to which they are attached that the sliding member is, in consequence of this looseness and the wear between the yoke and itself, allowed to move so far that it will sometimes strike an adjacent member; also, when the sliding member is in position for transmitting power, the wear and looseness may be sufficient to allow it to slip partly out of engagement with its mating member, so that in the case of a pair of gears only two-thirds or half the width of the teeth, measured across the gear-face, will engage with each other. This condition is a very undesirable one, on account of the greater stress that is brought upon the engaging portion of the teeth and the probability of producing a shoulder on the gear-teeth.

42. If a differential-gear set and a transverse jack-shaft are mounted in the same casing as the change-speed gears, as in a side-chain drive, the differential gears and jack-shaft should be examined for wear and lost motion in the same manner as has already been described for a rear axle having the differential gears enclosed in its housing. The jack-shaft and rear axle should be tested for parallelism when a side-chain drive is used.

43. Planetary change-speed transmission gears can generally be opened up for examination by loosening a collar on the shaft on which the gear set rotates and then slipping the case along the shaft, so as to gain access to its interior. In the common forms of planetary transmission gears, the most serious wear occurs either at the gear-teeth themselves or at the pins and bearings upon which the gears run. This remark applies especially to the planetary gears, each of which has its axis of rotation at one side of the shaft upon which the

entire set revolves. About the only remedy in such a case of wear is to provide new pins and new gears. It is possible, if new parts cannot be readily obtained, to bore out and bush the gears and make new pins. However, if the teeth of the gears are worn so as to be dangerously weak, there is no remedy except to install new gears.

Although the wear on the drum against which the friction band grips outside of the differential gear-set is generally not great enough to reduce the thickness of the drum so as to make it unsafe on account of weakness, nevertheless it should be examined for thickness, especially if there are any indications of abrasion or cutting on its surface, such as may be caused by a projecting rivet or other metallic part that rubs against the drum. The examination of the bands and clutch used on planetary transmission cases is mainly one for wear of the frictional parts.

EXAMINATION OF COOLING SYSTEM AND TIMER

44. A test for leaks in the radiator and the other parts of a water-cooling system can be readily made by filling the cooling system with water. This test is generally more complete if the engine is run while the test is being made.

The spark timer should be opened up, or even taken apart in some designs, and examined for the condition of wear of the moving parts. The parts that should be especially examined are the contact pieces. If rollers are used as stationary members, they should be tried for looseness on the pins that support them. Looseness beyond a very slight amount between such rollers and their pins should be remedied by inserting either larger pins or new parts.

ADJUSTMENTS AND REPAIRS

POWER-PLANT ADJUSTMENTS

LOCATING OF DEAD CENTERS

45. In connection with the setting of the valves of the engine, it is necessary to know the exact locations of the dead-center positions of the cranks. It is also convenient, but not necessary, to know these positions when timing the ignition. In most of the more recent engines, the dead-center positions are indicated by marks on the face of the flywheel that come opposite, or register with, a stationary mark or point when the crank is on a dead center. Many of the earlier engines do not have such markings, although they should be placed on all.

46. The dead-center positions of the crank of a single-cylinder engine can be located by the method here given, provided there is an opening in the cylinder through which a wire rod or a ruler can be inserted against the face of the piston. A petcock or the opening for a spark plug will answer. It will first be assumed that a straight opening through a petcock is available, this opening being in line with the direction of motion of the piston.

First, set the crank-shaft rotating in its normal direction so that it is about, but not exactly, one-fourth of a revolution from the position that brings the piston to the head end of the cylinder, the *head end* being the end farthest from the crank-shaft. Then, insert a wire through the open petcock or spark-plug hole until the end rests against the face of the piston. The wire should be a good fit in the petcock or spark-plug opening, so that it cannot move sidewise. Next, mark

the wire with a knife or a scriber so that the mark will be even with the end of the petcock or the face of the spark-plug hole. Without moving the crank-shaft, make a mark on the flywheel coinciding exactly with a similar mark on some stationary part; the mark on the stationary part will hereafter be termed the *reference mark*. Now turn the crank-shaft in the normal direction of rotation, past the dead-center position of the piston, and onwards, until, with the inside edge of the wire resting against the same spot on the piston face as before, the mark on the wire comes even with the end of the petcock or the face of the spark-plug hole. Opposite the reference mark, next make a mark on the flywheel in the same relative position as the first one. Then, make a mark exactly midway between the two marks first established on the flywheel; this third mark, which is permanent, indicates the exact head-end dead-center position of the crank when brought opposite the reference mark.

The crank-end dead center, corresponding to the farthest-out position of the piston, can be found in a similar manner.

The two marks indicating the dead-center positions of the crank-shaft must be diametrically opposite. In other words, the distance between them, measured in either direction around the face of the flywheel, must be the same. If it is not, the determination is not correct and should be made again

If the wire does not fit snugly in the opening through which it is inserted into the cylinder, it must be always kept in contact with the same point on the face of the piston. This is especially true when the piston face is not flat. Some pistons are crowned, others are concave, and still others are of irregular form on their faces. The latter applies especially to the pistons of two-cycle engines.

If there is no opening through which the wire can be inserted against the face of the piston, it may be necessary to remove some part of the crank-case so as to measure the distance of the piston from the end of its stroke. In such a case, the measurement is taken either from the end of the cylinder nearest the crank-shaft or from some convenient stationary part of the crank-case.

47. In a two-cylinder opposed engine, the mark indicating the head-end dead center of one piston will also indicate the crank-end dead center of the other piston.

In a four-cylinder vertical engine, with all the cylinders in a row on the same side of the crank-shaft and the cranks in pairs 180° apart, a mark indicating the highest dead center of one pair of pistons will indicate the lowest dead center of the other pair.

48. The dead center of an engine with offset cylinders can also be accurately determined in the manner given in Art. **46**, for the reason that the extreme positions of the piston represent the dead-center positions of the crank, which are the positions in which the center of the crank-shaft, the crankpin, and the piston pin lie in the same straight line.

SETTING THE IGNITION TIMER

49. The setting of the timer on a single-cylinder engine having a jump-spark ignition system can be accomplished as follows: Remove the spark plug from the cylinder, disconnect the wire from the spark plug, or make certain that no combustible mixture can enter the cylinder by opening the compression petcock or closing the spray-nozzle valve of the carbureter. Set the crank on the dead center corresponding to the completion of the compression stroke of the piston. This will be called the *compression dead center*. Advance the spark control slightly from its position for latest ignition. Move the rotor of the timer around on the shaft that drives it; this movement is in the same direction as that of the rotor when operating regularly. Continue to move the rotor very slowly in this direction until the primary circuit is closed by the timer, as indicated by the vibration of the trembler of the spark coil or by the passing of a spark. Stop moving the rotor as soon as the circuit is closed, and then fasten the rotor to its shaft without changing the position of any of the parts.

The slight advance given to the spark-control lever while setting the rotor allows for retarding the spark so that it will be certain to come after the dead-center position of the crank has been passed when cranking the engine to start it. This advance should be at least great enough to allow for variation in the time of the spark, on account of wear and consequent lost motion in the parts connecting the timer to the spark control. Otherwise, there would be danger of igniting the charge before reaching the dead center when cranking the engine to start it. The consequent backward kick of the engine is dangerous to the operator.

It may be found that the engine cannot be slowed down enough when the car is at rest with the spark lever in its extreme retarded position and the throttle closed as completely as possible without stopping the engine. The rotor of the timer should then be moved around on its shaft slightly in the direction opposite that of its rotation when operating regularly.

50. For a multicylinder engine, the setting of the timer for any one of the cylinders answers for all of them, provided the timer is properly constructed. It is well, however, to make a test to determine the instant at which the spark occurs in each cylinder when the crank-shaft is rotated slowly. This can be readily done by setting the timer so that the circuit is closed just as the crank comes to the dead-center position for any one of the cylinders. The spark should then occur at the corresponding dead center of each of the other cylinders at the instant that the primary circuit is closed. If the circuit is not always closed at the corresponding dead-center position of the crank, it will be necessary to correct the timer so as to close the circuits at the proper instant. The manner of making this correction depends on the form of the timer. In some timers, the contact pieces that give the earlier closing of the circuit can be shortened circumferentially so as to retard the timer contact until it corresponds with that of the timer that closes the circuit earliest relative to its own piston. In other timers, however, it is practically

impossible to correct them without making changes that amount to reconstruction.

51. If an individual vibrator coil is used for each cylinder of the engine, the spark may not occur at the same relative position of each piston, even if the primary circuit is closed at the same relative position of each corresponding piston. This irregularity, or lack of synchronism, is due to difference in the length of periods of lag at the different spark coils. When all the coils are of the same construction and size, the periods of lag will not generally be greatly different if the vibrators are adjusted to the same spring tension, as nearly as can be judged, and also to the same rate of vibration. The rate of vibration can be judged by the pitch of the sound emitted by the vibrator.

ADJUSTING A VIBRATOR

52. The amount of current that a spark coil requires for its operation depends a great deal on the tension of the vibrator spring and the rate of vibration. The vibrator can be best adjusted by the aid of an ammeter placed in the primary circuit to which current is furnished by either a battery or a direct-current generator. The makers of spark coils sometimes place upon the coil the amount of current that it should consume. About all that is then required is to adjust the spring tension and rate of vibration until the required current is registered by the ammeter. Usually, the current required lies somewhere between $\frac{3}{10}$ and 1 ampere.

The vibrator should be adjusted so as to give a rather highly pitched, but not a rattling or a tinny sound. In the absence of an ammeter to measure the current, this sound can be depended on for a fairly correct adjustment. If the current is overlarge, a spark will generally be distinctly visible at the vibrator contacts; and in the case of a greatly excessive current, small, reddish sparks will sometimes fly off from the contacts. This latter condition should not be allowed to continue for any length of time, as it indicates burning, or fusing, of the contacts, which will quickly destroy them.

The adjustment of the vibrator is practically the same when the primary current is supplied by a low-tension high-frequency alternating-current electric generator as when it is supplied by a battery or a direct-current generator. Where there are several coils and vibrators, all should be adjusted as nearly alike as possible.

SETTING A SYNCHRONOUS MAGNETO

53. The word *synchronous*, in connection with a magneto, is intended to indicate that the generator rotates at such a speed as to produce a maximum current at each instant an ignition spark is required. This excludes what are generally known as high-frequency alternating-current generators, which may be driven either by a belt or a friction wheel. The setting of the rotor of a synchronous magneto should be such as to give the maximum current at, or slightly before, the instant that the primary circuit is either opened or closed, according to the principle on which the magneto operates, it being assumed, for convenience, that an interrupter opens the circuit to form the spark.

In general, the rotor of the magneto should be set somewhat in advance of the position that corresponds to the maximum rate of change of magnetic flux through the core of the magneto winding. If the rotor is a shuttle-wound armature having the customary **H**-section core, the maximum current occurs when the armature core is in the position at which the end pieces of the **H** bridge the space between the magnet poles. In this position the stem of the **H** is at right angles to the two pole pieces of the permanent magnets. The following method can be used to set the armature of a synchronous magneto:

First, set the crank of the engine in its head-end dead-center position; then set the magneto armature in advance of the position that gives maximum current. The extent of this advance depends on the type of engine and the speed at which it is to run. For ordinary practice, an angle of 10° to 15° is a suitable advance in the direction of rotation of the magneto armature.

54. Some magnetos of the synchronous type are provided with an index hole into which a pin can be inserted for the proper advance of the armature when the crank is on the head-end dead center. Others have markings that register under corresponding circumstances.

Other makes of magnetos have index marks that are intended to register for a position of the crank different from that of the dead-center position. In one of these, the engine is set to bring one of the pistons into the position that it will occupy for the earliest ignition that is ever intended to occur. The rotor of the magneto is then set by its index mark. The setting of the magneto is that in which the rotor occupies the earliest position during its rotation that will give a current of sufficient volume to produce a spark strong enough for ignition.

55. Just what should be the setting of the crank for the earliest ignition is, in the absence of information from the manufacturer of the engine, a matter of judgment and trial. It is generally safe, however, to start with 10° before dead center for a medium or a slow-speed engine, and 15° for a high-speed engine. Speed here refers to the rate of rotation of the crank-shaft. An angle of 10° corresponds to one-thirty-sixth of a revolution, and may be laid off on the outer curved surface of the flywheel by taking a distance equal to one-thirty-sixth of the complete circumference of the flywheel. An angle of 15° corresponds to one-twenty-fourth of a revolution, and may be laid off on the flywheel in a similar manner. The circumference of a flywheel can be measured by wrapping a measuring tape around it.

56. The setting of a magneto that has a stationary armature and winding is carried out on the same general lines as is that of the type of magneto just discussed. The same condition of maximum-current position is the initial starting point from which the setting of the rotor is determined. When reference marks or index holes are provided, the setting is generally readily accomplished. In the absence of

these markings, however, judgment must be depended on at first and then verified by trial.

Manufacturers of magnetos are generally ready to give instructions regarding the method of setting them. It is rather unfortunate, however, that many magnetos without any marking to aid in this setting have been installed.

The gears that drive the magneto of the synchronous type should also be marked, in order that they may be placed with the proper teeth together after they have been removed for any purpose.

VALVE SETTING

57. Before taking up the study of how to set the valves of four-cycle engines, it will be well to review and fix in mind what takes place on each of the four strokes that complete the cycle. For this purpose, four positions of the crank-shaft, connecting-rod, and piston rod for a high-speed four-cycle

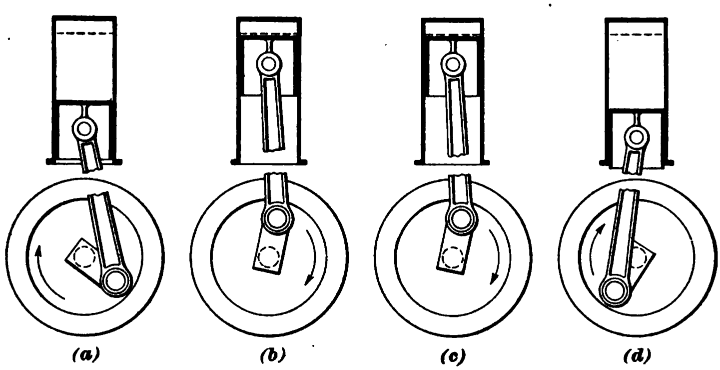


Fig. 2

engine are shown diagrammatically in Fig. 2. The exhaust opens some time before the end of the impulse stroke, as shown at (*a*), and closes soon after the beginning of the suction stroke, as shown in (*b*). The inlet valve opens almost immediately after the exhaust valve closes. The position of the parts when the inlet valve begins to open is shown in (*c*), and the inlet valve closes when the parts have moved to the

position illustrated in (*d*). The piston is now on its compression stroke.

58. Instead of dead-center marks, some modern engines have marks on the flywheel to indicate when the valves should begin to open and complete their closing. These marks are generally lettered in some manner to indicate the valve to which each mark refers. When a mark is brought opposite a reference point, the valve that corresponds to the mark should either begin to open or just settle down on its seat.

When the valves are lifted by a push rod, or lifting rod, in accordance with almost universal practice, the setting of the valves can be tested by placing a piece of tissue paper between the adjacent end of the lifting rod and the end of the stem of the valve to be tested. This can be done while the valve is resting on its seat, provided there is a slight space such as is ordinarily found in practice between the push rod and valve stem when the valve is closed. The crank-shaft should then be rotated in its normal direction of rotation until the flywheel mark corresponding to the valve has come within a short distance of the stationary reference point. The crankshaft should then be moved very slowly and the instant at which the paper is first pinched between the push rod and valve stem noted. As soon as this is done, rotating the crankshaft should be stopped. The mark on the flywheel should then register with the reference point. If the flywheel mark has not reached the reference point by the time the paper is first pinched tight, the valve opens too early. On the other hand, if the flywheel mark has gone past the reference point, the valve opens too late.

In order to test the time of closing of the valve, rotate the crank-shaft until the flywheel mark for the opening of the valve under test has come within a short distance of the reference point. Then rotate very slowly, as before, and pull gently on the tissue paper so as to note the instant that it can be withdrawn. Stop the rotation immediately, and note the position of the flywheel mark with regard to reference point. If the flywheel mark has not reached the

reference point when the paper can be withdrawn, the valve closes too early; but if the flywheel mark has passed the reference mark, the valve closes too late.

Each valve can be tested in succession in this manner.

59. Wear of the valve cam, cam-follower, lifting rod, or the end of the valve stem causes the valve to open later and close earlier. The lift of the valve is also generally reduced by the wear of any of these parts.

A loose cam, as one that is pinned to the cam-shaft with a pin that is too small or has become worn, will also cause the valve to open late and close early, even though the cam is of the proper form and has not worn. This assumes that the cam is so loose on the shaft that it slips forwards after lifting the valve and at the time that the valve is beginning to close. The pressure of the valve spring, which acts through the connecting parts, has a tendency to push the cam forwards while the valve is closing.

If some of the parts wear so that the cam-shaft permanently lags behind, the valves will be late both in opening and in closing. Such a case may occur when the gear that drives the cam-shaft is pinned or keyed to the cam-shaft and the pin or key is too small and hence has partly sheared.

There should always be a small clearance between the adjacent ends of a valve stem and the rod or other device that lifts the valve. This space allows for variation of the lengths of the parts due to the heating and cooling of the engine. The space should be at least as wide as the thickness of heavy writing paper; a much wider space is used in some engines, but it should never exceed $\frac{1}{32}$ inch. The duration of the period during which a valve is kept open can be varied to a slight extent by changing the width of this space. The smaller the space, the earlier will the valve open and the later will it close; the lift of the valve will also be greater with the smaller space between the end of the valve stem and the lifting member.

60. If there are no marks on the flywheel to indicate the valve setting, then the first step is to mark the flywheel.

Before doing this, however, it is necessary to decide on the positions of the crank at which the valve is to open and close. Practice shows a great variation with regard to the setting of valves.

In the more modern automobiles whose engines run at medium speed, the exhaust valve generally opens from 30° to 40° before the crank-end dead center is reached, and the valve settles on its seat when the crank has gone from 5° to 10° beyond the dead center. The inlet valve opens ordinarily a very short time after the exhaust valve closes. It is sometimes set so as to begin to open just at the instant the exhaust valve completes its closing. In most engines, however, an allowance of 5° of rotation of the crank-shaft, or slightly more, is allowed between the closing of the exhaust valve and the opening of the inlet valve. The inlet valve closes when the crank has gone past the crank-end dead center 10° or more.

61. A valve that opens before the crank has reached the nearest dead-center position is said to have *lead*, which is measured either in degrees or parts of a revolution. A valve that does not open until after the crank has passed the nearest dead center is said to have *lag*.

The amounts of lead and lag of the valves that will give the best results, which generally means the most power for the engine, depend on numerous conditions, chief among which are speed of rotation, the size of the valve opening, and the lift of the valve. In slow-speed engines, the lead and lag are generally much less than in high-speed engines. In racing engines, the lead of the exhaust valve is sometimes 45° or more, and the lags of the different valves are correspondingly large.

In the earlier engines, especially those of slow speed, it is common to find that both the exhaust and the inlet valve close on the head-end dead center, while the inlet valve opens almost immediately after the head-end dead-center position of the crank is reached. In present-day engines the valves are closed before the dead centers are reached.

62. The manufacturers of automobiles of the better class usually determine the best valve setting for their engines by exhaustive experiments, and they give this information either in their instruction books, or on application. Some manufacturers give the opening and closing of the valves in inches, measured from the beginning of the piston stroke; others give a diagram, such as the one shown in Fig. 3, showing the timing of the valves on the face of the flywheel, either in degrees or in linear measurements from the dead-center marks, or in both.

Referring to Fig. 3, which is the valve-timing diagram for a well-known four-cylinder air-cooled engine, there are marks at *a* and *b* corresponding to other marks on the face of the flywheel. On the actual flywheel, the mark corresponding to *a* on the diagram is *1–4*, and the mark corresponding to *b* is *2–3*. When one or the other of these two marks is opposite a stationary reference mark, made on the

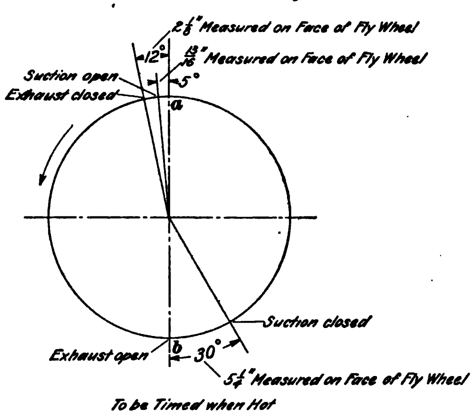
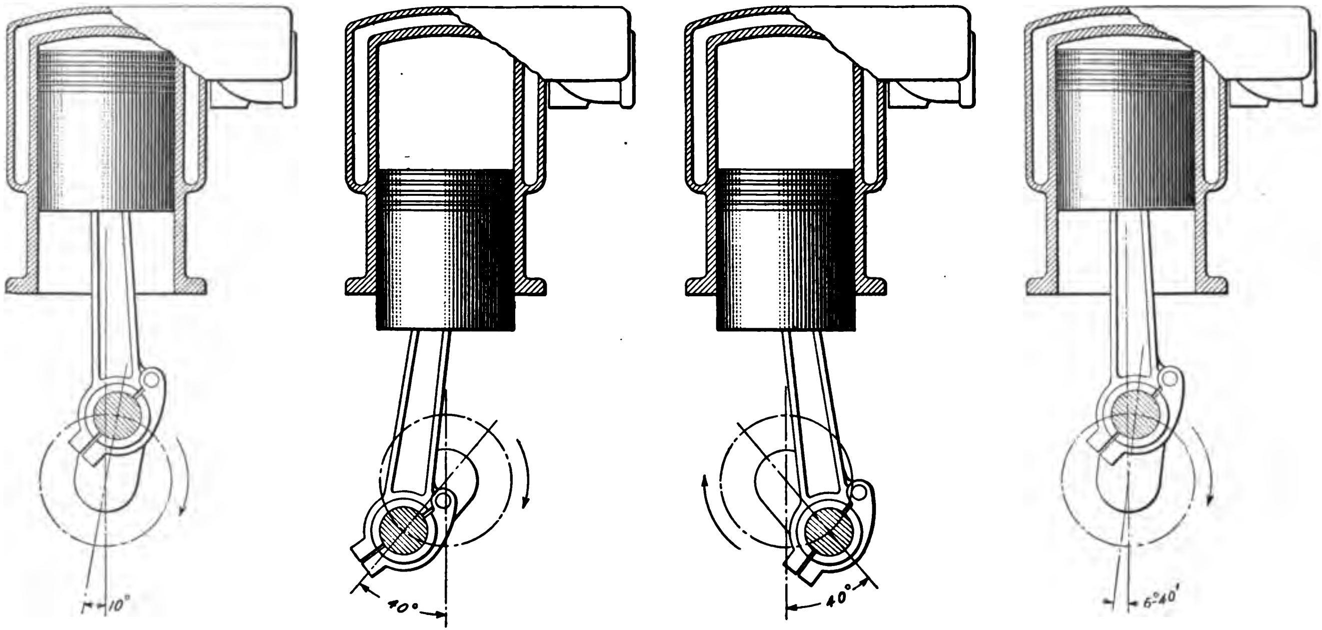


Fig. 3

flange of one cylinder, it means that the cranks of cylinders *1* and *4* or *2* and *3* are on their dead centers. Thus, if the mark *a* registers with the mark on the cylinder flange, it means that the pistons in cylinders *1* and *4* are at the head-end limit of their stroke, and that the cranks of cylinders *1* and *4* are at their head-end dead centers. As the cranks of cylinders *1* and *4* and cylinders *2* and *3* are 180° apart, the pistons in cylinders *2* and *3* will be at the crank-end limit of their stroke; that is, the cranks for cylinders *2* and *3* will be at their crank-end dead centers. Similarly, when the mark *b* is opposite the stationary reference mark, it means that the cranks of cylinders *2* and *3* are on their head-end dead centers, and as a



Inlet Valve opens — *Inlet Valve closes* — *Exhaust Valve opens* — *Exhaust Valve closes*

Fig. 4

necessary consequence the cranks of cylinders *1* and *4* are on their crank-end dead centers.

It will be noted, on referring to Fig. 3, that in this particular case the suction valve opens before the exhaust valve closes. This a very uncommon practice, but has been proved necessary for best results in the air-cooled engine for which the diagram is intended. In practically all water-cooled engines, the exhaust valve closes before the suction valve opens.

63. In Fig. 4 is shown the valve-timing diagram of a well-known water-cooled engine, in which the inlet valve opens 10° after the crank passes the head-end dead center and closes 40° after the crank passes the crank-end dead center. The exhaust valve opens 40° before the crank-end dead center is reached, and closes 6° 40′ after the head-end dead center is passed. Consequently, the exhaust valve closes $10° - 6° 40' = 3° 20'$ before the inlet valve opens.

The manufacturer of the engine for which Fig. 4 gives the valve timing places marks on the flywheel that register with a stationary reference mark and letters these marks "Inlet Opens," "Inlet Closes," "Exhaust Opens," and "Exhaust Closes." This practice is now common and does away with all measuring from marks representing the dead-center positions of the crank.

64. If the flywheel has only the dead-center positions marked on it, and the manufacturer furnishes the time of opening and closing the valves in degrees, their angular measurements may be transformed into linear measurements as follows:

Rule.—*Multiply the diameter of the flywheel, in inches, by 3.1416 and by the number of degrees lag or lead. Divide the product of the three factors by 360.*

Example.—Referring to Fig. 4, it is seen that a manufacturer recommends a lag of 10° and 40° for the inlet valves, a lag of 6° 40′ for the exhaust valves, and a lead of 40° for the exhaust valves. If the flywheel is 20 inches in diameter, how far from the dead-center marks should marks designating the valve opening and closure be placed?

SOLUTION.—Applying the rule given to the opening of the inlet valve, the distance is

$$\frac{20 \times 3.1416 \times 10}{360} = 1.745, \text{ say } 1\tfrac{3}{4}, \text{ in. Ans.}$$

Applying the rule to the closing of the inlet valve, the distance is

$$\frac{20 \times 3.1416 \times 40}{360} = 6.981, \text{ say } 7, \text{ in. Ans.}$$

Applying the rule to the opening of the exhaust valve, the distance is

$$\frac{20 \times 3.1416 \times 40}{360} = 6.981, \text{ say } 7, \text{ in. Ans.}$$

Applying the rule to the closing of the exhaust valve, and bearing in mind that $6° \ 40' = 6\tfrac{2}{3}° = \tfrac{20}{3}°$, the distance is

$$\frac{20 \times 3.1416 \times \frac{20}{3}}{360} = 1.163, \text{ say } 1\tfrac{9}{32}, \text{ in. Ans.}$$

For laying off the lag or lead from the dead-center marks, a flexible scale or steel tape may be used.

65. The gears that drive the cam-shaft for operating the valves of an engine should be marked at or near the teeth in such a manner that they can be placed together properly after they have been removed from the engine. Before removing the cam-shaft or any of the gears used to drive it, care should be taken to see whether the gears are marked to indicate which teeth should mesh. If no marks for this purpose are found, they can be made by filing a notch in the end of a tooth of one gear and by making similar notches in the ends of the two teeth of the intermeshing gear between which the marked tooth of the first gear fits. Other methods of marking the gears will doubtless suggest themselves, such as making a punch mark with a pointed punch on the end or side of the tooth of one gear, and another mark just below or on the side opposite the corresponding space between the teeth of the intermeshing gear.

RUNNING-GEAR REPAIRS

BODY-SPRING REPAIRS

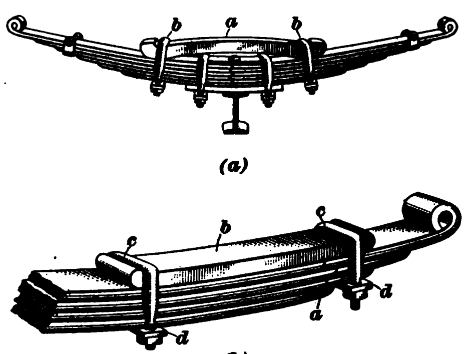
66. It frequently happens that one or more of the leaves of a spring that supports the body of the car breaks off short.

(a) (b)

FIG. 5

If the break is such that the leaves of the spring still hold the axle in position and allow only the body of the car to settle, a rubber bumper of one of the forms shown in Fig. 5 will generally serve to support the car without further injury until some point can be reached where repairs, more or less permanent, can be made. The ring bumper, shown in Fig. 5 (*a*) is best adapted to light cars, and the bumper shown in (*b*) is suitable for heavy ones.

If the car has no other bumpers, or if it is desirable to keep the body more level than is done by the bumper, a block of wood or a piece of board set in between the spring and the body or the frame of the car will hold the body up. This repair, of course, sacrifices the elasticity of the spring and makes riding uncomfortable. It may be



(b)

FIG. 6

desirable to use both a block of wood and a bumper when the latter is at hand.

67. If the spring breaks completely in two, as shown in Fig. 6 (*a*), the *spring repairer a* can be used temporarily. When of sufficient strength and securely bolted in place by the clips *b*, it will carry the car almost as well as an uninjured spring.

If the leaves of the spring are broken off at some distance from the axle, as shown in Fig. 6 (*b*), the fracture being at *a*, the spring can be repaired by bolting a curved bar of metal *b* to the spring, as shown. The curvature of the repair bar should be about the same as that of the spring when the usual load is resting on it. The clips *c* must be strong and very firmly clamped in place by tightening the nuts hard against the cross-bars *d*.

68. Some springs used in automobiles can be welded and tempered by a blacksmith familiar with the working of spring steel. Springs properly repaired in this manner will often give as good service as whole springs, or, sometimes, they will give even better service. The special alloy steels, usually referred to as high-grade steels, cannot be satisfactorily repaired by welding. If only one leaf is broken, a new one may be made of ordinary spring steel and used until a complete new spring or a new leaf can be obtained.

REPAIRING OF BREAKS

69. A broken rod or tube may be temporarily repaired on the road by placing on each side of the break a bar of metal

Fig. 7

and then wrapping the broken bar and side pieces with wire, as shown in Fig. 7. The method is similar to that of binding

splints on a broken bone. Of course, more than two bars may be wired to the rod, if it is considered necessary. If

FIG. 8

difficulty is encountered in trying to wrap the wire tight enough to hold the parts firmly together, the wire may possibly be tightened by driving under it, alongside the splints, wire nails, a punch, a cold chisel, or any other convenient wedge-shaped piece. It is desirable, if square or flat bars are used as splints, to round the corners somewhat in order to prevent them from cutting the wire, especially if any pieces are driven under the wire to tighten it as just described. When twisting the ends of the wire together to hold them, there should not be any more stress put on the wire than is necessary to accomplish the fastening. For such purposes, mild-steel or iron wire is generally better than a hard or tempered wire. A highly tempered wire is entirely unsuitable.

70. A more permanent repair than is possible by the method described in the preceding article can be made to a broken rod by the method indicated in Fig. 8, which shows a tube, such as a piece of gas pipe, slipped over the broken ends and held in place by rivets that pass through the broken rod and the pipe. The latter should be small enough to fit tightly on the rod. It can generally be put on more readily by smoothing up and slightly tapering, or beveling, the broken ends of the rod, as indicated. If the inside diameter of the pipe is slightly smaller than the rod, the rod can generally be driven into it after heating the pipe. The shrinkage of the pipe will cause it to grip the rod firmly when cold.

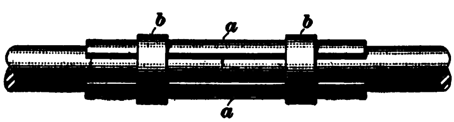


FIG. 9

In the absence of any tubing or pipe, fairly good temporary repairs may be made in the manner shown in Fig. 9. As indicated in this figure, a couple of bars *a* are hammered to a somewhat rounded shape to fit on the broken rod, and these are fastened by means of rings *b* forged to the proper size and then shrunk on. Rivets can be used or not used, as the conditions of the case require. When the joint is made properly in this manner, they generally are not necessary if the rod is subjected to thrust only, but when it is required to withstand a stress tending to pull the broken ends apart, rivets will probably be needed.

71. Broken parts can sometimes be successfully welded directly together, or the ends can be cut off and a new piece welded in. Welds are not always reliable, however, and should not be used in the case of such parts of a car as the rods of the steering gear, upon which safety depends to such a great extent.

72. If not broken into several pieces and distorted, broken castings, such as a cracked gear-case, crank-case, or axle housing, can be repaired by one of the processes suitable for such repairing. Among these processes may be mentioned brazing and welding. The latter may be done with a blow-pipe that may use an oxyhydrogen flame or oxyacetylene flame, or it may be done in the foundry by the method of flowing a current of molten metal over and past the fracture so as to melt away a portion of the original casting and replace that portion by new metal that is fused into the old part remaining. The metal used in this flow-and-fuse method is ordinarily the same, or nearly the same, as that in the original castings; thus, bronze would be used for mending a bronze casting; cast iron, for mending a cast-iron casting; aluminum, for an aluminum casting; and steel, for a steel casting. Brazing does not generally give as strong a joint in castings as does welding by the flow-and-fuse method; yet, for certain conditions, as when mending a cracked water-jacket on a cylinder in which the water-jacket is integral with the cylinder, brazing is generally entirely satisfactory. There are

special methods of brazing applicable to cast iron and similar materials that are generally employed in foundries.

Whether it is advisable to have a casting repaired depends, of course, on the comparative cost of a new casting and the cost of repairing the old one; or, it may depend on the facility with which the repair can be made or a new part obtained. The best method of arriving at a decision as to whether a broken casting shall be repaired is to consult an establishment making a specialty of such work, and to have the part examined by them if possible.

73. Broken parts, if of mild steel, can readily be welded together, and even some of the special shapes can be welded by one ordinarily skilful in handling such work. This refers to such forms as bars, channels, or angles, which make up the frame of the chassis. These parts are sometimes of such shape and size that they can be readily welded after heating in an ordinary forge. Other frames, however, can be welded only by some of the special processes, such as a blowpipe flame or an electric welder, or by the use of some such metal-fusing substance as that known as *thermit*. This substance gives an intense heat by the combustion of portions of the composition and furnishes liquid metal that will fuse into and adhere to the part to be welded.

REPAIRING OF PIN JOINTS

74. Pin-connected joints that have worn loose and out of round can be permanently repaired if there is sufficient material, or stock, in the parts, by boring out the hole to a larger size by means of a rose bit, or rose reamer, and fitting a new pin. This method of repair is applicable to the joints of the steering mechanism, as used on some machines, including the pin joints on which the steering knuckles of the front wheels swivel. Universal joints are frequently made with pin connections that can be repaired in this manner. When bushings are used in pin-connected joints, the bushings can be removed and new ones substituted. A new pin of standard

size is generally required to make a good fit when new bushings are put in.

The connections of the carbureter, the throttle, and the spark timer, when pin-connected joints are used, as is often the case, can be repaired in the manner just described.

POWER-PLANT REPAIRS

FITTING OF PISTON RINGS

75. Badly worn or ill fitted piston rings are the most prolific source of lack of compression. If the cylinder shows no excessive wear and is free from grooves, new piston rings may be fitted, and, if this is properly done, good compression will be obtained. It is a waste of time, however, to try to remedy faulty compression by fitting new piston rings to a badly worn cylinder. The latter should be rebored or reground, unless a new cylinder can be obtained for less than the cost of reboring and fitting a new piston.

Assuming that the cylinder is in good condition, a piston ring may be considered as having reached the end of its usefulness when its ends, on trying the ring in the cylinder, gap open more than $\frac{3}{32}$ or $\frac{1}{8}$ inch. To try the ring in the cylinder, it must be removed from the piston. The following method is a good one for this purpose: Flatten the end of a rather large piece of copper wire, so that the flattened end resembles a thin screwdriver. Put the flattened end of the wire under the piston ring where it is cut in two, and lift the ring out of its groove just far enough for one end to slide over the piston-ring pin when the ring is twisted around in its groove by the free hand. If the pin is high enough, the ring can generally be removed from the groove by twisting it around still farther and pressing the raised end lightly sidewise, so that it cannot spring back into the groove. If there is no piston-ring pin, or if the pin is not high enough to keep the ring out of its groove, the ring can be held up by a small block of wood. This block

should not be thicker than the depth of the groove. It may be more convenient to use strips of thin sheet metal instead of blocks; sheet copper or tin will answer. The strips can be slipped under the ring when it is lifted by the copper wire. Strips of this kind are useful for slipping the ring on or off over other rings or grooves. The ring should not be sprung open any farther than is necessary when removing it or putting it in place. Piston rings are usually made of cast iron and consequently break easily.

76. If, upon trying in the cylinder, a piston ring removed from the piston is found to gap open only a very little and shows an even bearing throughout, it is not worn enough to do any harm; however, if the gap is large and there is considerable wear, a new piston ring is required. Piston rings obtained from some manufacturers require actual fitting to the cylinders, while other manufacturers finish their cylinders and piston rings so finely that if care is observed in putting the rings over the piston, no fitting whatever is required.

A new piston ring should be tried at several points in its groove before putting it over the piston, in order to determine whether it fits sidewise. If the ring is too wide to go into its groove so as to move freely, but is almost correct, it can be reduced in width by rubbing its sides on a piece of fine emery cloth or emery paper that lies on a perfectly flat surface. The ring should be laid flat on the emery cloth and then rubbed so as to keep the pressure uniform over the entire side of the ring. A piston ring should fit freely in its groove, but it should not have any side play. Before applying a new piston ring to the piston, it should also be tried in the cylinder to make sure that it is not too long. If it is too long, the slot will have to be filed until the ring will just enter the cylinder with the ends of the slot butting together.

77. To fit new piston rings to a cylinder so that they will be tight—it being assumed here that they were not machined with sufficient accuracy—requires patience and considerable skill, which can be obtained only by experience in this kind of work.

The new rings having been sprung over the piston and properly placed in their grooves, the inside cylinder wall should be coated very thinly with red lead or Prussian blue mixed with oil, and the piston inserted in the same position it will occupy when the engine is assembled. After pushing and pulling the piston back and forth a few times, it should be removed from the cylinder. The marking points will indicate the high spots of the piston rings, which must be lowered by filing or by scraping, or by both, until trial in the cylinder shows the rings to have a very even bearing all around.

Some repairmen try to fit new piston rings by ***running in***, as it is called. This process, while advisable when the rings have been previously given a good bearing by filing and scraping or by excellent machine work, cannot be recommended when the new rings fit poorly. Running in piston rings consists in belting the assembled engine to some convenient source of motive power and turning the crank-shaft rapidly for from 8 to 24 hours, or even more, feeding lubricating oil frequently to the cylinder or cylinders. If the rings fit badly, they can only wear to a fit by wearing away not only their high spots but also the cylinder walls opposite the high spots.

78. The piston-ring pins that prevent the rings from working around in their grooves should be located some distance apart circumferentially, and each pin should be in its own groove, so that the cuts in the rings will not come near each other. If all the cuts were to come in line with each other along one side of the piston, leakage past the piston would be almost certain to occur. Piston-ring pins are not always used in four-cycle engines, but they are necessary in two-cycle engines to prevent the ends of the rings from getting opposite the ports over which the rings must pass. If the ends of a ring get into such a position as to pass over a port, there is danger of their springing out and striking against the edge of the port. The result would generally be a broken ring.

79. Until a person is familiar with the process, replacing a piston in its cylinder generally requires considerable patience and time. This is especially true if the bore of the cylinder is not chamfered at the end so that there is a beveled surface for the piston rings to strike against as they enter the cylinder. If there is no chamfer at the end of the cylinder bore, the rings must be pressed down in their grooves as they enter the cylinder. This can sometimes be done with the hands, but if the rings are narrow and stiff, it is generally necessary to use a tool of some kind. A piece of wood or a stiff copper bar will generally answer. Nothing harder than the metal of the rings should be used. It may even be necessary to wrap a band of copper wire or stout cord around each ring to hold it while it is entering the cylinder. The task generally requires two persons when the cylinders are cast in pairs, and when four cylinders are cast together, the work is still more difficult.

GRINDING OF VALVES

80. The first steps in valve grinding are to remove the valve and to place on its bearing surface a small quantity of abrasive that has been mixed with a thin grease. A mixture of vaseline and finely powdered emery is suitable for this purpose. Other abrasives that may be used instead of emery are ground glass, carborundum, etc. If the valve to be reground is an inlet valve, the port leading into the cylinder should be carefully closed with a piece of cloth or a bunch of cotton waste, so as to prevent the abrasive from getting into the cylinder. This precaution, however, is not necessary in the case of an exhaust valve. The valve should be put in place and rotated back and forth. The top of the valve is generally provided with a slot into which a screwdriver can be inserted for rotating the valve. The valve should be lifted occasionally in order to allow the abrasive to get between the surfaces to be ground. Lifting the valve can be facilitated by placing a small coil spring on the stem so that it will press against the guide when the valve is put in place. Some pressure will then be necessary to keep the valve against its seat

when rotating it. When this pressure is released, the valve will rise from the seat. It may be necessary to renew the abrasive frequently during the grinding of a valve that is in bad condition. The grinding should be continued until the entire surface has a dull appearance when wiped clean. A finer abrasive may then be used to give a smoother finish to the surfaces.

In cleaning the valve and port, especially if it is an inlet valve, care should be taken to remove all abrasive. If any is left on the inlet valve or its port, it will be almost certain to go into the cylinder. The presence of an abrasive in the cylinder will injure the cylinder wall and piston rings.

The grinding of a valve may be done more readily by using a small brace, similar to that used by carpenters, instead of an ordinary screwdriver.

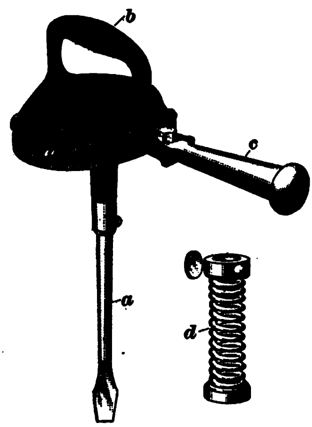


FIG. 10

81. When a great amount of valve grinding is to be done, as in a large repair shop, it may be advisable to use some form of hand-operated grinding device. One of these grinding devices is illustrated in Fig. 10. The point of the screwdriver blade *a* is placed in the slot of the valve when operating the tool, and the handle *b* is grasped in one hand; then by rocking the handle *c* back and forth with the other hand, the screwdriver is given a rotary motion in alternating directions, and the valve, of course, follows the motion of the screwdriver. The spring *d* is placed under the valve to lift it from its seat when the pressure of the screwdriver against the valve is relieved.

Another form of valve-grinding tool is shown in Fig. 11. It resembles the one just described in several features, but, instead of an oscillating driving handle, it has a crank that turns through complete revolutions. The crank, of course,

can be rocked back and forth in order to give an alternating motion to the valve that is being ground.

82. After grinding a mechanically operated valve, it should be noted whether the valve stem strikes against the valve lifter or comes too close to it. In either case, the stem should be shortened by filing or grinding off its end; or, if an adjusting device is provided on the lifter, adjustment should be made to give the proper space between the lifter and the valve stem.

FIG. 11

If the valve stem is too short and there is no means of adjusting its length or that of the lifter, adjustment can be made either by placing a thimble-shaped cap of thin metal over the end of the stem of the lifter or by drilling a hole into the end of either of them, whichever is most convenient, and then driving a pin into the hole.

If a hole is drilled, it is better to make a rather small one and then insert a pin that has a head that will come down solid against the stem or lifter. The shape of the pin used in such a case would be something like that of a rivet in its blank form. The pin should be driven tightly into the drilled hole, but even if it should come loose, it cannot get out of place, because the stem and lifter are always near each other.

It may sometimes be more convenient to lengthen the valve stem or the lifter if the latter is simply a short round bar. This can be done by stretching either one of them by hammering. Judgment must be used as to whether this should be done.

REPAIRING A WATER-JACKET

83. If the water-jacket of a cylinder has split, through freezing of the water, it can often be repaired at small cost in various ways. If the crack is very small, it may be rusted up. For this purpose, a saturated solution of sal ammoniac is made and poured into the jacket. A plug, screwed into one of the water openings, is drilled and tapped for a small tube, by which air pressure is put on the liquid in the jacket by means of a tire pump. The cylinder is so laid that the crack is at the bottom, and after several hours it will be found that the edges of the crack have rusted solid from the action of the sal ammoniac.

Another method of closing a crack is to drill and tap a series of $\frac{1}{8}$- or $\frac{3}{16}$-inch holes as close together as practicable for the entire length of the crack, the first and last holes being at the extreme ends of the crack, in order to prevent it from extending farther. These holes are plugged with cast-iron plugs turned and threaded for the purpose, and the job is completed by rusting in with the sal-ammoniac solution as just described.

Still another method of repairing a crack in a water-jacket is to fill it with an iron cement known as Smooth-on. This cement is applied while the cylinder is hot, being calked into the crack.

When brazing facilities are available, it is much better to braze a cracked cylinder than to try rusting it, as the chances of securing a permanent repair are much better.

The best and most permanent repair of all is by means of autogenous welding, in which a new piece of metal is fused with the two sides of the crack under an oxyhydrogen or oxyacetylene flame. Shops equipped for doing repair work of this kind are now located in most of the large cities.

RELINING A CONE CLUTCH

84. A friction leather for a cone clutch is not straight like a piece of belting when flattened out, but is curved as shown in Fig. 12 (*a*), because the leather is fitted to a cone instead of to a cylinder. The radius of the circle of which the outside edge *b d* of the leather forms a part when flattened out is equal to the slant height of the cone, as shown by the distance *a c* in Fig. 12 (*b*). The point *c* is found by extending the sides *a a′* and *b b′* of the cone until they meet at the apex *c* of the cone. The distance *a c* and the angle of the cone cannot be determined when the parts of the clutch, of which the cone forms a part, are together, or in place on the car. The usual method of procedure, therefore, is to take off the old leather from the cone of the clutch, and use it as a pattern for cutting a new leather.

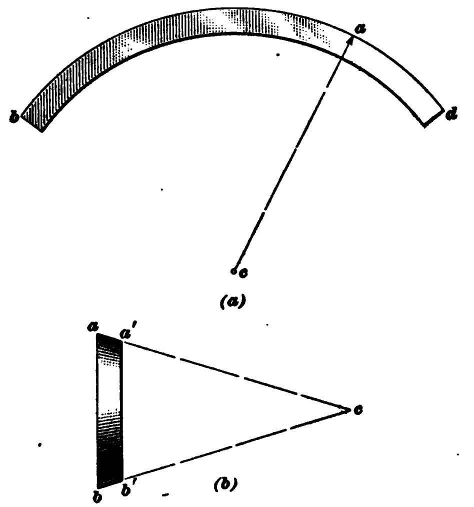


Fig. 12

The length of a rectangular piece of leather required for a new cone leather can be taken as three times the large diameter of the cone, including the leather on it. The width of the leather strip depends on the angle of the cone and also on the width of the cone. In any ordinary design, a rectangular piece four times as wide as the width of the leather strip that goes on the cone will be sufficient. If the leather procured for making the cone covering is too narrow, the strip can be cut out in two pieces, each long enough to go half way around the cone. These pieces will answer as well as a single piece.

although they may be a little more difficult to put in place. Most metal cones have four or more holes drilled close together near the point where the ends of the leather meet.

In putting the leather on the cone, a convenient method is first to fasten one end by a rivet placed through one of the holes, near the point where the ends are to come, and then to wrap the leather around the cone, holding it as nearly as possible in position. The leather can then be cut so that the ends come within $\frac{3}{8}$ to $\frac{1}{2}$ inch of each other. Then, after drawing the two ends together, they can be permanently fastened by putting in the rivets. The leather can then be pressed at some other point on the cone as far as it should go, and riveted in place. It is generally best to make the second fastening diametrically opposite the ends of the leather. The next fastening can then be placed midway between the places that are already fastened, thus making four fastenings, each a quarter of the way around the cone from the other, and so on until all the rivets are in place.

Except in cases where the exact position of the holes in the leather is known by previous trial or experience, it is well not to punch holes in it until it has been pressed in place on the cone and there marked for the holes. The heads of the rivets should be countersunk in the leather, so that they will not bear against the cone before the leather has been worn down to half its thickness or less. Soft copper is the best material for rivets, because copper will not injure the clutching surface opposite the leather facing in case the rivets rub against it. Ordinary harness rivets will generally answer.

RADIATOR REPAIRS

85. The repairing of radiators, generally speaking, is a task beyond the facilities of the ordinary automobile repair shop, although in such shops minor repairs can often be made in a more or less permanent manner. Sometimes small leaks in radiator tubes can be closed by soldering, provided the leaky tube is located where it can be reached.

In some instances, the tube can be thickly coated with an iron cement known as Smooth-on. This cement, the setting of which is hastened by heat, must be applied while there is no water in the tube.

If in a gilled-tube radiator in which each tube is provided with thin tin or copper disks, a tube in one of the inside rows has sprung a leak, it is usually the best practice to send the radiator to the makers for repairs, as there are very few radiators of this type that permit of disassembling and reassembling without proper facilities. This statement applies with equal force to radiators having thin, flat tubes either straight or crimped into zigzag shape, connected to headers.

In radiators of the cellular type, in which the water surrounds the tubes, a burst tube may be repaired effectually by driving a piece of soft wood into each end, thus cutting the burst tube out of service. If the tubes leak at their joints with the header plates, an expert can repair the leaks by soldering; a person not familiar with this kind of work, however, is liable to do more harm than good.

REFITTING OF BEARINGS

86. If a plain bearing has become badly worn, either from natural wear or from lack of lubrication, it can often be repaired by refitting. First of all, the shaft journal must

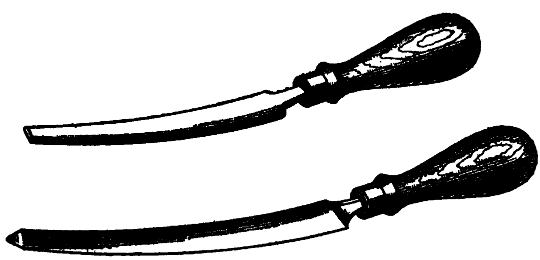


FIG. 13

be put in good condition by turning or grinding; if the journal is only very slightly scored, drawfiling with a very fine file may be sufficient. By *drawfiling* is meant drawing a

file along the work while the file is held at right angles to the direction in which it is moved.

The journal having been repaired, the box must be fitted to the journal by filing and scraping, or, if only slightly injured, by scraping alone. For this purpose, a scraper is used. Such a tool can be made by grinding off the teeth of a half-round or three-cornered file and smoothing down the edges with an oilstone. Fig. 13 shows two forms of scrapers that can be bought from supply houses.

The ordinary method of using a scraper is to grasp it by both hands as it lies lengthwise in the box to be scraped, and then draw it around the box in the direction that the journal rotates. One of the cutting edges is pressed against the metal of the box as the scraper is thus drawn around.

In order to obtain a good fit by scraping, a small quantity of some such substance as a thin mixture of red lead and oil, or of lampblack and oil, should be rubbed very lightly on the surface of the journal, which is then put in place and rotated slightly. Upon removing the journal, it will be found that certain spots in the box show traces of the marking substance; these are the high spots against which the journal rubs. The high spots should be scraped off until the markings are evenly distributed over the part of the box against which the journal should bear.

It is generally not advisable for a box to bear against its journal all the way around; it is sufficient if the box touches throughout two-thirds of its circumference. The places where it is not necessary for the journal to touch the box are near the lines of division of the two halves of the box; in other words, near the edges of each half box.

A hot box is sometimes caused by the ends of the box pressing against the collars of the journal. A journal that has collars should always have some end play in its box in order to prevent this end binding from taking place.

FITTING A NEW CRANK-SHAFT

87. When putting a new crank-shaft, and possibly also new bearings, into an engine, it frequently happens that the journals of the shaft are slightly too large for a running fit in the new boxes. The usual method under such conditions is to scrape the boxes so that they will fit the journals properly. The first step should be to determine whether the crank-shaft is straight; in other words, it should be determined whether all the main journals are in line. This can be done by placing the crank-shaft between the centers of a lathe and rotating it. In the absence of special tools for determining the lack of truth of running as the shaft rotates, a piece of iron or soft steel can be fastened in the tool post of the lathe so that its blunt end can be brought up against the journals of the crank-shaft, one at a time. By rubbing some chalk or some red lead moistened with oil on the journals, it can be distinctly seen whether or not the tool touches the journal as the shaft is rotated. If the journal runs true, the tool will scrape off the chalk or red lead in a ring of uniform width completely around the journal. However, if the journal is out of true, the ring will not be of a uniform width, or it may even not extend completely around the journal, but only around what is generally called the *high* part of the journal. It is advisable to test the end journals first to determine whether they run true with their centers. If it is found that they do not run true, the most convenient method of procedure is to support and run the end journals in bearings, which may be a pair of steady rests on the lathe, and then to test the intermediate journals for truth of running. The end journals will, of course, run true when they are supported in bearings that fit them and are rigidly held in position.

If the journals of the crank-shaft do not run true, it is hardly advisable to make any attempt to straighten the shaft, for if it is made of a good quality of steel, such as is used in the better class of automobiles, it cannot be straightened without injury, except by some such process as peening

with a hammer. Peening, however, should not be attempted by any one not skilful in such operations. In fact, it is generally not advisable to attempt to straighten a bent crank-shaft.

If the crank-shaft at hand must be used, despite the fact that it runs slightly out of true, one of the best methods of getting a proper fit, so far as diameter of bearings and journals is concerned, is to make a straight test shaft or try shaft of exactly the same diameter as the journals. If all the journals are not of the same diameter, the shaft must vary in diameter to correspond. This try shaft can then be used instead of the crank-shaft, the bearings being scraped in the usual way to fit the journals. The extent to which the diameter of the bearings can be increased by scraping is not more than a very few thousandths of an inch. The method of determining the areas where metal is to be scraped off the bearings was explained in Art. **86.**

GENERAL REPAIRS

GASKETS

88. Some of the pipe joints and other connections about an automobile are made tight by inserting between the pipe flanges or other parts a piece of packing cut to a suitable shape and known as a **gasket.** Even if the joints are made tight, metal to metal, when the car is new, it frequently happens that they become warped or injured during service so that a gasket must be used to keep them tight. Generally, the gasket is cut from a sheet of suitable material, but special gaskets made up of two or more materials are also used.

The kind of material used for a gasket naturally depends on such conditions as the presence or absence of oil, water, gasoline, and heat. If oil, gasoline, or great heat is present, the gasket should not have any rubber in it, for the rubber is softened by either oil or gasoline, and both softened and burned by heat. About the only materials that can be used

for gaskets where there is great heat, as in the exhaust pipe, are asbestos and copper. Sheet asbestos interwoven with copper wire is very suitable for such use. It can also be used where oil and gasoline come into contact with it. In places where there is oil or gasoline, but no great heat, vulcanized wood fiber, leather, and even strong paper can be used to advantage. All these materials are less expensive than the woven asbestos mat.

Copper-asbestos rings and other forms of gaskets are made by bending a piece of sheet copper over so that it has two thicknesses between the surfaces that it is to pack. Asbestos is placed between the two thicknesses of the gasket, so as to form a cushion against which they press when the parts of the joint are drawn toward each other to tighten the joint.

In small couplings and joints, such as those on oil and gasoline pipes, a thin ring of sheet lead (the metal) makes an excellent gasket. Such joints can also often be successfully made tight by putting a little soap or some rubber cement on the parts that press against each other to make the tight part of the joint.

It should always be carefully noted whether there is any possibility of the gasket being squeezed from between the surfaces of the joint so as to close the passage either partly or wholly. Leather and sheet-rubber packing are especially apt to be squeezed out in this manner. Lead packing may also be squeezed out enough to close a passage almost entirely; this is especially the case if the gasket is originally thicker than it should be.

By coating one side of an asbestos gasket with graphite, and the other side with varnish, such as shellac varnish, the joint will separate easily when taken apart, and the gasket will adhere to the varnished side.

SOLDERING AND BRAZING

89. Soldering is a process of joining metallic surfaces by means of a soft fusible alloy, called *solder*, that is applied in a molten state. The ordinary solder is composed of equal

parts of tin and lead, and can be obtained in the form of both bars and wire. Since it is comparatively soft, it is often spoken of as *soft solder*.

Soldering can be done either with a soldering iron or by holding the piece to be soldered in the flame of a torch, such as is used by plumbers, until it becomes hot enough to melt the solder. The solder will not take hold well unless some flux is used. Zinc chloride dissolved in alcohol makes a very effective and harmless soldering solution. The chloride can be purchased at most drug stores in a granular form. A thimbleful of this granular chloride to a couple of ounces of alcohol works well. The solution can be put on both before applying the solder and while soldering; for this purpose, a piece of rag or cotton waste on the end of a stick or a piece of wire may be used. If the chloride cannot be obtained, it can be made in the liquid form by dissolving zinc in hydrochloric acid. There should be more zinc put into the acid than it will dissolve, so that no acid will remain. The liquid thus obtained can be mixed with alcohol, using about twice as much alcohol as of the zinc chloride. Powdered resin acts as a flux to liquefy solder and make it adhere to the parts to be soldered. It is not nearly so satisfactory, however, as the chloride solution.

Acid should not be used under any condition as an aid to soldering; it will generally attack the metal and produce injurious results.

If the parts to be soldered are oily, it may be expedient to clean them with gasoline before trying to solder. In the case of an insulated wire whose insulation has been cut off, the wire should be carefully scraped to remove any of the rubber compound that may adhere to it.

In order to make a success of soldering, two things must be kept in mind: the surfaces to be united must be absolutely clean, and the work must be heated sufficiently for the solder to flow.

90. Brazing is a process of joining metallic surfaces by means of a fusible alloy that is very hard compared with

solder. The fusible alloy most generally used is sold under the name of *spelter*, and has about the same melting point as yellow brass. Jewelers' silver solder has a lower melting point than spelter, which makes it valuable for use on work that cannot be brought to a high heat without injury. In the absence of spelter, ordinary cast brass or brass wire may be used. In brazing, as in soldering, a flux is required. One of the best fluxes, as well as the cheapest, is the ordinary calcined borax sold for household use.

The metallic surfaces to be united must be made absolutely clean, which is done by filing, scraping, or grinding. The two parts to be united must be held together firmly and closely, and some flux and spelter must be applied at the joint. The parts are then heated sufficiently to melt the spelter, which does not occur until a rich red heat is obtained. More spelter and flux may now be applied to the joint. After this has melted and flown over the surfaces of the joint, the parts are removed from the fire and allowed to cool slowly. The heating of the parts may be done in many ways, according to the existing facilities and the size of the job.

The materials that can be united by brazing are wrought iron, cast iron, malleable-iron casting, steel casting, steel, copper, some bronzes, and brass. Obviously, only such materials as have a higher melting point than the spelter that is used can be united by brazing.

In brazing it is important to hold the parts in such a position while heating them that the molten spelter can flow into the joint; molten spelter will flow downwards, but not upwards.

REPAIRING OF TIRE AIR PUMPS

91. Air pumps used for inflating tires ultimately fail to operate properly through the wearing out of the leather washers that are used for making a tight joint between the plunger, or piston, and the bore of the tube in which it operates. These leather washers have the form illustrated in Fig. 14. The shape is that of a disk slightly flanged around the edge and pierced by a hole to fit over the end of the

plunger rod. They can be purchased at most garages. In case a washer is needed and none is at hand, it can be made from a piece of soft leather, which should be as nearly as possible of the same thickness as the old washer. The heavy leather used for boots and shoes will generally answer. If this kind of leather is not available, a piece of harness leather or even leather belting trimmed down to the proper thickness will answer fairly well. In making a washer, it should be cut sufficiently larger than the bore of the pump in which it is to be used, to allow for the flange. After a washer thus made is put in place, its edge can generally be flanged very much more readily after moistening it with water. This is not true of all kinds of leather, however.

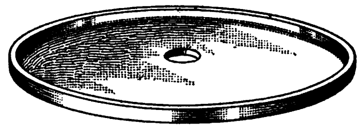


Fig. 14

It may be found that the pump will not act right at first, on account of leakage past one of these home-made washers, but after a while the leather will generally shape itself so as to fit closely against the bore of the pump. A little lubricating oil generally aids in making a tight fit. The ordinary cylinder oil is the most convenient to use, but it may gum along the sides of the pump cylinder after awhile, when it can be cut off by the application of a little kerosene. Gasoline may be used for the same purpose, but after using gasoline care must be taken to oil the inside thoroughly before using the pumps. Neatsfoot oil is better than ordinary lubricating oil for softening the pump washer.

If the pump fails to work after a new leather washer has been fitted, the probability is that one or more of the check-valves are out of order and need cleaning. If steel balls are used as check-valves, it is possible that they have rusted, and, if this is the case, new ones should be substituted.

REPLACING OF COTTER PINS AND SECURING OF NUTS

92. The replacing of cotter pins, or split pins, and other fastening devices should be carefully attended to as soon as the parts they fasten are put in place. It is always unsafe to leave the cotter pins out while putting the parts together, with the expectation of putting them in after the work is otherwise completed. If it is found extremely inconvenient to put the cotter pins in while putting the parts together, there should at least be a piece of wire or string put in the hole where the cotter pin belongs, as a reminder that a pin is to be put in. The string or wire should be long enough to be readily seen, so that it will not be overlooked.

A nut that works loose can be kept in place by wrapping a piece of ordinary cord or twine around the bolt between the end and the part against which the nut bears. The nut will not generally work loose after it is tightened down against this string, but will remain in place until the string either decays or is burned. If the nut is in a very hot place, as on the exhaust pipe, asbestos cord will answer the same purpose very well. Also, a split lock washer placed under a nut that persists in working loose will generally hold it in place.

BALL-BEARING REPAIRS

93. Steel balls for ball bearings can be obtained of any diameter by variations of one- or two-thousandths inch for all except the larger sizes, in which, however, they can be secured in steps of two- to four-thousandths inch. When putting new balls in a bearing, the whole set should be new, and it should be made certain that all are of the same size. If one ball is larger than the rest, as may be the case when a new ball is put in with old ones, or if all the new ones are not of the same size, the load will practically fall on the larger ball or balls most of the time. This is apt to be injurious to both the balls and the race on which they roll.

In order to take up wear, it is customary to use what are called *oversized balls* in all forms of ball bearings, despite the

fact that makers of ball bearings do not recommend this practice. The introduction of larger new balls in place of the worn old ones, with annular ball bearings, gives the best results when the bearing has been subjected to such wear, on account of end thrust, that the groove in which the balls run is of considerably larger radius than that of the balls.

94. In selecting a new set of balls for a bearing, the safest way is to measure several diameters of each ball with a micrometer, rejecting those which are not truly spherical and those which are not of proper size. Balls should be true to shape within one ten-thousandth inch, and all balls used in one bearing should not vary more than twice this amount in size; also, every ball should be so well polished that no grinding or polishing mark or defect of any kind is visible through an ordinary pocket reading lens. One automobile maker allows a variation of five ten-thousandths inch in the diameter of $\frac{3}{8}$-inch balls, and does not even condemn a ball if it is one-thousandth inch over or under size. This is not good practice, however.

95. When ball bearings of the cup-and-cone type or roller bearings of the cone type are used in the road wheels of an automobile, it sometimes happens that the wear of the balls and cones that are inside or next to the body of the car allows the wheel hub to move in so that the cap at the end of the hub comes in contact with the end of the spindle, provided the latter happens to be long enough to clear the cap only slightly when new. When this condition exists, the hub cap is sometimes forced off by the pressure of the spindle against the cap. The remedy may be to cut off the end of the spindle, to recess or force the end of the cap outwards, to put in new bearings, or, if the cone next to the body of the car is not greatly worn, to put in new balls of a larger size than the old ones. The latter method has proved to be satisfactory in some cases, although it sometimes happens that the groove formed in the cone by the old balls is of a radius almost exactly equal to that of the balls. In such a case, the larger new balls will not touch the bottom of the

groove, but will roll on its edges. As a result, it is generally necessary to adjust the bearings soon after the balls have been put in and used, on account of the rapid wear that occurs on the cone by the new balls riding on the edges of the groove.

REMOVING OF PARTS FROM SHAFTS

96. For removing a gear, a wheel, or a pulley from its shaft, the device illustrated in Fig. 15 is convenient. The method of using it is to hook the ends *a* over the rim of the pulley or the edge of the wheel, and to force the end of the screw *b* against the end of the shaft. In this way the hooks and pulley are drawn toward the end of the shaft.

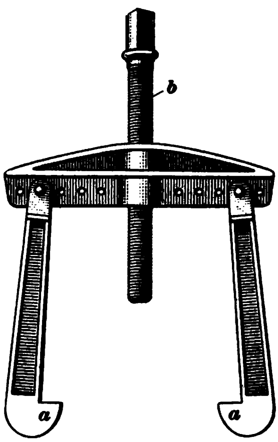


FIG. 15

When applying a device of this nature to a rear wheel that sticks tightly to its axle, it may be necessary, or at least desirable for safety, to put the ends *a* of the hooks over two bars placed across the wheel, instead of allowing the hooks to catch the brake drum fastened to the wheel. The pull of the hooks directly on a brake drum may injure or fracture the drum if the wheel is on the axle very tight.

97. Fig. 16 illustrates a home-made wheel puller, suitable for a large variety of work. It consists of a flat clamp and a **U**-shaped clamp connected together by two bolts. One of the clamps can be placed back of the parts to be pulled off and the other allowed to rest against the end of the shaft; then, by tightening the nuts on the ends of the bolts, the parts can be moved relative to each other. Such a device can be used for removing a driving road wheel from its

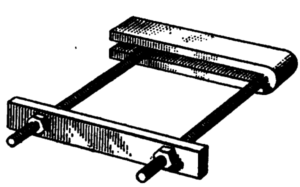


FIG. 16

axle, if the clamp is made so as to clear the brake shoe, axle, and other parts. When applied for this purpose, a piece of shafting or a block of iron may have to be placed between the flat clamp and the end of the axle, or a more satisfactory method may be to drill a hole through the center of the clamp and tap it to receive a screw similar to that shown in Fig. 15. A device of this kind can be used to remove the flywheel from the crank-shaft when the flywheel fits directly on the shaft by a forced fit. This construction is employed in several of the early types of the cars, and is still followed in modern practice in some cars. It may be added that the more usual method adopted for modern cars is to flange the end of the crank-shaft and then fasten the flywheel to the flange by means of bolts.

98. A device such as that shown in Fig. 15 can be used to remove the ring that forms the race of a ball bearing from the inner end of the spindle of a knuckle joint on which the front wheel of the car runs, provided the edge of the bearing ring projects out far enough to catch the hooks back of it. These races are forced on so as to be extremely tight. Sometimes, however, even though the tool gets a sufficient grip, it may be difficult to pull off the ring unless the mechanical puller is very strong and rigid.

Some ball-bearing cones and cups are so applied to the parts that support them that a punch or drift can be driven behind the cone or cup and through the supporting member for forcing them apart.

TOOLS

99. While a large variety of machinist's tools is necessary for the making of extensive repairs, most of the ordinary repairs and replacement of worn parts by new ones, as well as roadside repairs, can be executed with the tools usually carried in a tool kit on the car.

The opinions of different automobilists naturally vary as to what the contents of a tool kit should be and as to what supplies should be carried. The experience of many has

indicated, however, that it is desirable to have at least the following tools:

One 6-inch and one 10-inch narrow-jaw, all-steel, monkey-wrench.

One screwdriver with end of blade $\frac{3}{8}$ inch wide, and one with end of blade $\frac{5}{8}$ inch wide.

One pair of 6-inch side-cutting plyers.

One machinist's ball-peen hammer weighing 1 pound.

One $\frac{1}{8}$-inch and one $\frac{3}{16}$-inch punch.

One 8-inch flat file, medium cut; one 8-inch half-round file, medium cut; one 8-inch three-cornered file, medium cut; and one 10-inch round file, medium cut.

One cold chisel not less than $\frac{1}{2}$ inch wide.

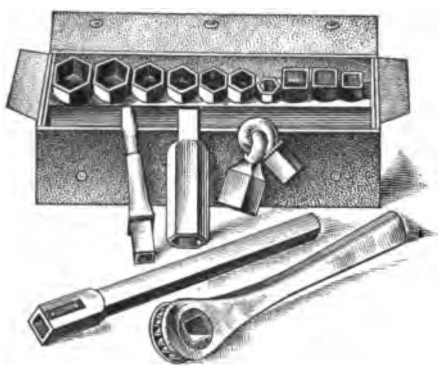


FIG. 17

One 10-inch cotter-pin puller.

One small oil can.

One 10-inch all-steel pipe wrench.

Such special wrenches as are supplied with the car.

Tire tools and tire-repair outfit.

One good jack.

One soldering copper weighing $\frac{1}{2}$ pound, together with soldering solution and a small quantity of solder.

The following supplies should be carried in every tool kit:

One box of assorted cotter pins.

One box of assorted washers.

One sheet each of medium and fine emery cloth.

Some copper and iron wire.

A few assorted bolts.

100. For reaching bolts, nuts, and screws that are in positions inaccessible for ordinary wrenches, a socket wrench becomes a necessity. Socket wrenches in sets are found on the market in numerous varieties, most of which

are very convenient and well constructed. A small set of socket wrenches is illustrated in Fig. 17. It will be seen that the general form of the socket wrench is that of a tube shaped to a form corresponding to that of the nut or bolt head, which is either hexagonal or square. An extension bar is ordinarily provided so that a considerable reach can be made between the nut and the handle or wrench used for turning the socket. A universal joint is also customarily provided in order to facilitate the removal of nuts and screws that are in such positions that they cannot be easily reached by a straight socket wrench. A screwdriver or other tool can be used as well as a socket in connection with the extension bar and universal joint.

INDEX

NOTE.—All items in this index refer first to the section, and then to the page of the section. Thus, "Automobile chains, §1, p43," means that automobile chains will be found on page 43 of section 1.

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